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OVERVIEW OF THE 'PAVER' PAVEMENT MANAGEMENT SYSTEM AND ECONOMIC--ETC(U)
MAR 82 M Y SHAHIN, S D KOHN

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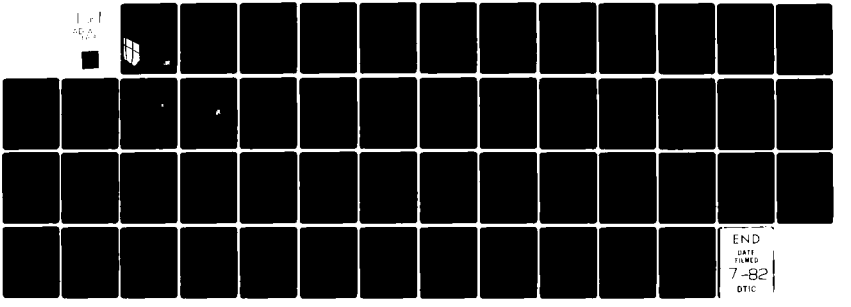

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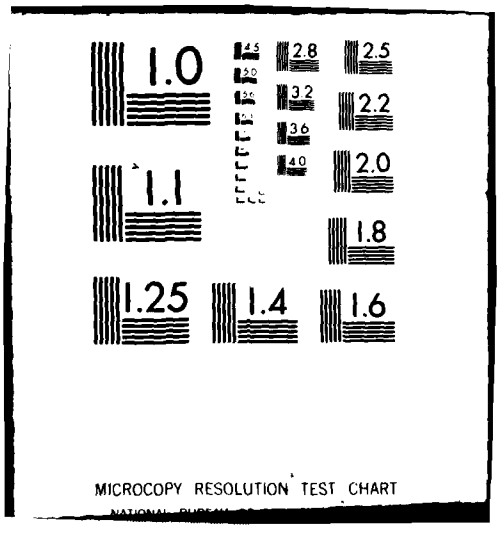
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MICROCOPY RESOLUTION TEST CHART

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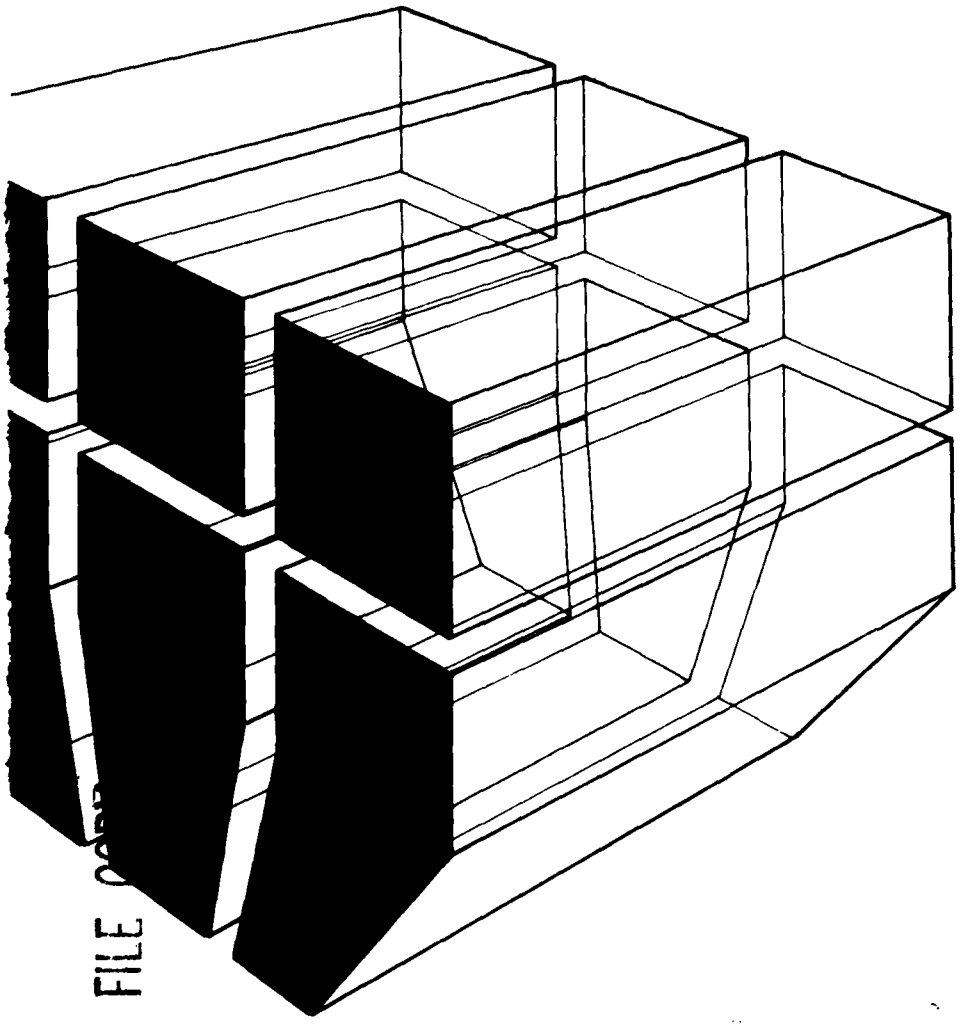
TECHNICAL MANUSCRIPT M-310
March 1982

# OVERVIEW OF THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

and

# ECONOMIC ANALYSIS OF FIELD IMPLEMENTING THE "PAVER" PAVEMENT MANAGEMENT SYSTEM



by
M. Y. Shahin
S. D. Kohn



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| 1. REPORT NUMBER<br>CERL-TM-M-310 | 2. GOVT ACCESSION NO.<br>AD-A126 | 3. RECIPIENT'S CATALOG NUMBER<br>327 |
| 4. TITLE (and Subtitle)<br>OVERVIEW OF THE "PAVER" PAVEMENT MANAGEMENT SYSTEM and ECONOMIC ANALYSIS OF FIELD IMPLEMENTING THE "PAVER" PAVEMENT MANAGEMENT SYSTEM | | 5. TYPE OF REPORT & PERIOD COVERED<br>FINAL<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>M. Y. Shahin<br>S. D. Kohn | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>U.S. ARMY<br>CONSTRUCTION ENGINEERING RESEARCH LABORATORY<br>P.O. Box 4005, Champaign, IL 61820 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>4A762721AT41-D-040 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS | | 12. REPORT DATE<br>March 1982<br>13. NUMBER OF PAGES<br>48 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED<br>15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

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paver
pavement management
economic analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

OVERVIEW OF THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

This paper presents a brief overview of PAVER and the capabilities it offers its users. PAVER is a pavement management system designed for use by military installations, cities, and counties. The PAVER capabilities

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presented are: data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning.

## ECONOMIC ANALYSIS OF FIELD IMPLEMENTING THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

The paper presents the results of an economic analysis performed on implementing the PAVER system at a military installation. PAVER is a pavement management system developed by the U.S. Army Corps of Engineers over the past 10 years for use by military installations, cities, and counties. It provides the user with practical management tools including data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning.

The economic analysis was performed based on data collected during a Prototype Evaluation Test (PET). The PET consisted of PAVER data gathering for the entire installation, and monitoring the utilization and cost of use of PAVER by the installation personnel. The PET consumed two years; however, the official cost-monitoring period was 4 months. The monitoring team consisted of 21 pavement engineers. Two economic analyses were performed: (1) an analysis based strictly on the data collected during the 4-month PET "PET Data Comparison," and (2) an analysis based on estimated times and costs for expected annual use "Estimated Data Comparison."

The results of the "PET Data Comparison" showed that the annual cost of pavement management using PAVER is approximately 50 percent that of the cost of the current operating method. The results of the "Estimated Data Comparison" showed that the annual cost of pavement management using PAVER is approximately 30 percent that of the current method.

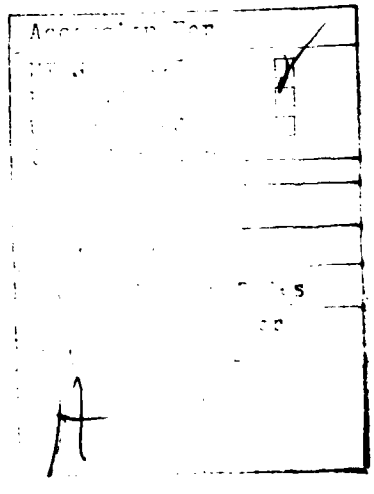
## FOREWORD

These papers were prepared for presentation at the 61st Annual Meeting of the Transportation Research Board, held in January 1982.

The work was conducted at the U.S. Army Construction Engineering Research Laboratory (CERL). The work was funded by the Air Force Engineering and Services Center, Tyndall AFB, FL, under Project Order Number S-80-7, dated 9 November 1979; and by the Directorate of Military Programs, Office of the Chief of Engineers, under Project 4A762721AT41, "Military Facilities Engineering Technology," Task D, "Management of Maintenance and Operation," Work Unit 040, "Technical Manual on Pavement Management."

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.





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# OVERVIEW OF THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

## INTRODUCTION

"PAVER" is a pavement management system designed for use by military installations, cities, and counties. The system was developed and tested over the past 10 years and is currently being implemented by several agencies, including Fort Eustis, Great Lakes Naval Training Center, and the City of Mesa, Arizona. This system was developed by the U.S. Army Construction Engineering Research Laboratory under the auspices of the Office, Chief of Engineers, U.S. Army Corps of Engineers. It has been extensively tested prior to its implementation. The objective of this paper is to provide an overview of PAVER, with emphasis on what is available to the system users. Details of the system's development and results of an economic analysis of its implementation have been documented elsewhere (ref. 1, 2).

PAVER provides the engineer with a practical decision-making procedure for identifying cost-effective maintenance and repairs on roads and streets. The System 2000 is the database manager. This system and other "interface" programs provide the user with report generation capability for critical information. This information allows objective input to the decision-making process.

PAVER provides its users with many important capabilities. These include data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning. The following sections describe these capabilities and provide example reports for each area.

## DATA STORAGE AND RETRIEVAL

The PAVER database is a custom-designed data structure defined on a commercially available computer database manager called System 2000. (System 2000 is a registered Trademark of the Intel Corp.)

The data structure consists of 12 data groups (see Figure 1) which are linked together to form a tree structure. Storing the data in this structure enables the user to retrieve information based on its connection to other data in the database. Space is available in each data group to store specific items related to that data group. The Pavement Structure data group shown in Figure 2 is an example.

The data can be stored and retrieved through special "interface" programs (Fortran or Cobol programs) or through the access language of the database manager. These programs are interactive, so the user has immediate access to the database. The programs are designed to supply the information in useful format.

## PAVEMENT NETWORK DEFINITION

An installation's (city's) pavement network consists of all surface areas that provide accessways for the ground or air traffic (airfield pavements). This network must be divided and identified in order to use the database. Networks are divided into Branches, Sections, and Sample Units. Following are brief definitions of these items:

(1) A Branch is any identifiable part of the network which is a single entity and has a distinct function, such as an individual street.

(2) A Section is a division of a Branch which has consistent structural composition, construction history, and traffic volume.

(3) A Sample Unit is the smallest unit of the network and is an area of the pavement section used during inspection.

The database provides information on the pavement network through reports such as "Lists" or "Inventory." Figure 3 shows a typical output of the "Inventory" report. This report provides general information about specific Branches or Sections, thus providing the user with overall inventory information.

## PAVEMENT CONDITION RATING

A key component of any pavement management system is a condition rating procedure. The PAVER system uses the Pavement Condition Index (PCI), a composite index of the pavement's structural integrity and operation condition. It is a numerical index from 0 to 100, with 100 representing excellent condition. The PCI is determined based on quantity, severity, and type of distress, as illustrated in Figure 4. The PCI was developed to agree closely with the collective judgment of experienced pavement engineers.

The PCI has been divided into seven condition categories, ranging from "excellent" to "failed," as shown in Figure 5. These categories are useful for developing maintenance policies and guidelines.

The PAVER database uses reports such as "PCI", "Inspect", and "Sample" to provide PCI information. Figure 6 shows a typical output of the "Inspect" report, which provides the user with PCI and distress information. The report can be used to prepare desk estimates of repairs and to determine history of pavement condition.

## PROJECT PRIORITIZATION

Project prioritization is an immediate payoff of pavement network definition and pavement condition rating. The "PCI" report can be used for this purpose. It lists pavement sections in an increasing order of PCI. Figure 7 is an example report output. The information in the report can be sorted based on pavement surface type, pavement rank (functional class), traffic type and volume, PCI range, or a combination of factors. Therefore, the report can be used to prioritize projects based on the user's policy.

## INSPECTION SCHEDULING

The inspection schedule report has been developed to maintain current condition data with efficient inspection level. This report produces a plot and list of the pavement sections to be surveyed for the next 6 years for any type of Branch Use (roadway, parking, etc.) and surface type (asphalt, Portland cement, concrete, etc.).

The schedule is based on two criteria. One is the minimum PCI a given pavement type is allowed to reach, and the second is the rate of deterioration (loss of PCI points per year). The user inputs the minimum PCI values and the years allowed between inspections for various deterioration rates. The PCI for the selected sections is then predicted by a straight line extrapolation, based on the maximum slope from either the last inspection or construction/overlay date (see Figure 8). Sections reaching the minimum PCI within 6 years or reaching the time limit based on the rate of deterioration will be selected for inspection in the appropriate year.

Figure 9 shows a typical Inspection Schedule output with plot and list of cases. The example shown is for primary roadways with asphalt concrete surfaces. Using this report, the engineer can keep the pavement network database up to date with minimum effort.

## DETERMINATION OF PRESENT AND FUTURE NETWORK CONDITION

An overall frequency of condition report has been developed to help plan future M&R and to inform management of the network condition. The report shows an estimated frequency of condition (based on the PCI scale) for the year requested. The pavement sections included in the report can be selected based on Branch Use, Pavement Rank, and Surface Type.

The frequency is estimated as in the Inspection Schedule report, using a straight line extrapolation of the PCI. Figures 10 and 11 show typical outputs of this report. These two figures show the estimated frequency of occurrence for the same set of pavement sections for two different years. The extrapolation presumes no major repairs (such as slab replacement, overlay, etc.) have occurred between the last inspection and prediction dates. Thus, the impact of performing no major repairs can be seen.

## DETERMINATION OF M&R NEEDS

A decision process has been devised for determining the M&R needs of a pavement section. Figure 12 is a flow diagram of this process. A first-level decision can be made, based on the PCI value, type of distress, and deterioration rate. PAVER provides reports such as PCI and Condition History to help the user make the first decision. The PCI report is an ordered listing of sections ranked by PCI (Figure 7). The Condition History report can be used to determine the rate of deterioration; the report plots the PCI over time for a given section. The plot shows the PCI at each inspection date and linearly extrapolates a point 5 years beyond the last inspection date. Figure 13 is an example of this report. The type of distress can be determined from the Inspect report, shown in Figure 6.

If a pavement section does not require further analysis, routine maintenance practices can be continued. Routine maintenance includes practices such as spall repair, crack filling, etc. Using maintenance guidelines for specific distress types, such as those shown in Table 1, the user can input a repair policy. This policy is used in a program called "MRG" to estimate the type and cost of routine repair to specific sections. The "MRG" report can also be used to compute the cost of overlay after distress repair. Figure 14 shows an output of the "MRG" report.

If a section requires further analysis, an evaluation summary is completed for the section. The evaluation is based on structural capacity, roughness, skid, and other relevant factors as shown in the top half of Figure 15. Complete guidelines for performing the evaluation are presented in ref. 1. Feasible M&R alternatives are identified based on the results of the evaluation as shown in the bottom half of Figure 15. This figure is an output of an Evaluation Summary report that was developed based on input from many experiences (maintenance engineers). The output from the report is general. Therefore, the engineer needs to select specific alternatives and perform the design based on the user agency policy. This may include using nondestructive testing.

## PERFORMANCE OF ECONOMIC ANALYSIS

Several repair (or construction) alternatives may be considered feasible for any given pavement section. To help select the appropriate alternative, an economic analysis program has been developed and added to the system. The program allows the user to input initial costs, periodic maintenance costs, and separate future maintenance costs. Figure 16 shows a typical input, and Figure 17 gives a corresponding output. As shown, the user is provided with the initial cost, present value, equivalent uniform annual cost, and equivalent uniform annual cost per square yard.

The program allows the users to vary interest rates, inflation rates, repair costs, and timing so that their effect on alternatives can be easily analyzed. Figure 18 is an example analysis which shows the effect of interest and inflation rates.

## BUDGET PLANNING

A Budget Planning report was developed to provide an estimate of the rehabilitation dollars required over a 10-year period for a given level of condition. The report is based on the user's input of minimum PCI levels for various Branch Uses and Pavement Rank. The user also inputs unit repair costs based on pavement Surface Type and the PCI scale; i.e., the cost of repair can be varied, depending on the PCI value. Thus, the increased cost of differing rehabilitation can be anticipated. The program also takes into account the inflation rate. Figure 19 shows an example output of this report.

This program predicts, for each pavement section, the year in which the minimum PCI is reached and calculates the cost of repair. The prediction is the straight-line prediction procedure explained in the Inspection Schedule report.

## SUMMARY

This paper has presented a brief overview of PAVER--a pavement management system for military installations, cities, and counties. PAVER assists engineers and planners with pavement management by providing the database and computational capabilities. These capabilities are: data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning.

## REFERENCES


1. Shahin, M. Y., and S. D. Kohn, "Pavement Maintenance Management for Roads and Parking Lots," Technical Report M-294, U.S. Army Construction Engineering Research Laboratory (December 1981).

2. Kohn, S. D., and M. Y. Shahin, "Economic Analysis of Field Implementing the PAVER Pavement Management System," technical paper submitted for presentation at the 1982 TRB annual meeting.

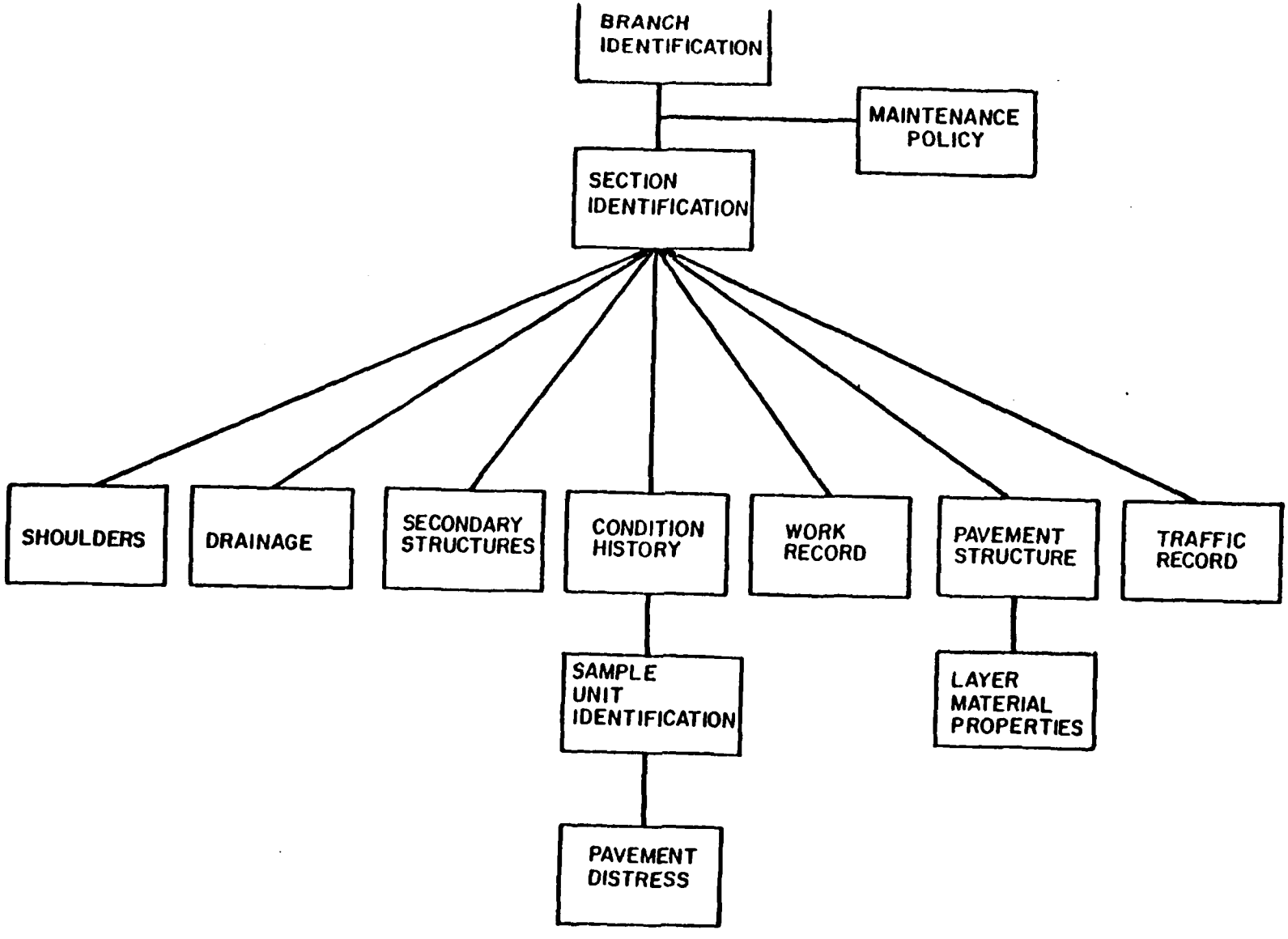



Fig 1. Paver Data Structure

```
2500*  PAVEMENT STRUCTURE (RG IN 1000)
  2501*  DATE CONSTRUCTED (DATE IN 2500)
  2502*  LAYER CATEGORY (NAME X(10) IN 2500)
  2503*  LAYER MATERIAL CODE (INTEGER NUMBER 999 IN 2500)
  2504*  LAYER MATERIAL (NAME X(20) IN 2500)
  2505*  LAYER THICKNESS (DECIMAL NUMBER 99.9 IN 2500)
  2506*  TYPE OF COATING (NAME X(10) IN 2500)
  2507*  LAYER COMMENTS (NON-KEY NAME X(39) IN 2500)
  2508*  PAVEMENT STRUCTURE UPDATE (NON-KEY DATE IN 2500)
  2509*  FACTOR 2509 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
  2510*  FACTOR 2510 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
  2511*  FACTOR 2511 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
  2512*  FACTOR 2512 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
  2513*  FACTOR 2513 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
  2514*  PSTR-CONCAT (NAME X(19) IN 2500)
  3100*  LAYER MATERIAL PROPERTIES (RG IN 2500)
    3101*  TEST DATE (DATE IN 3100)
    3102*  TEST TYPE (NAME X(31) IN 3100)
    3103*  TEST VALUE (DECIMAL NUMBER 9(5).9999 IN 3100)
    3104*  TEST UNIT (NON-KEY NAME X(13) IN 3100)
    3105*  FACTOR 3105 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
    3106*  FACTOR 3106 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
    3107*  FACTOR 3107 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
    3108*  FACTOR 3108 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
    3109*  FACTOR 3109 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
    3110*  LMAT-CONCAT (NAME X(26) IN 3100)
```

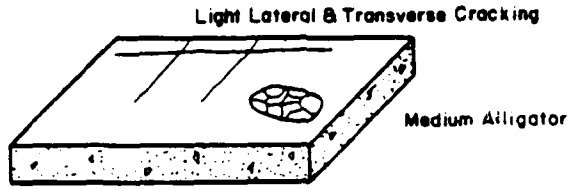
Fig 2. Pavement Structure Data Group

```
REPORT DATE-  09/28/81

                                INVENTORY
                        NON-FAMILY HOUSING PAVEMENTS

                                  SURF    BRANCH        PAVEMENT        AREA
                                  TYPE      USE           RANK          (SY)
----------
IWASN WASHINGTON NORTH
      SECTION 01                  AC      ROADWAY       PRIMARY         4007
      FROM- ROUTE 105
      TO-   CL MADISON AVE

      SECTION 02                  AC      ROADWAY       PRIMARY         6651
      FROM- CL MADISON AVE
      TO-   N'LY SIDE HINES CIR

      SECTION 03                  AC      ROADWAY       PRIMARY         4000
      FROM- S'LY SIDE HINES CIR
      TO-   CENTER OF SOMERVELL

      SECTION 04                  AC      ROADWAY       PRIMARY         6340
      FROM- CENTER OF SOMERVELL
      TO-   N'LY EDGE TAYLOR

      SECTION 05                  PCC     ROADWAY       SECONDARY       4453
      FROM- S'LY EDGE TAYLOR
      TO-   N'LY EDGE WILSON

                                                  TOTAL BRANCH AREA     25451

          TOTAL AREA OF SELECTED NON-FAMILY HOUSING PAVEMENTS           25,451
```

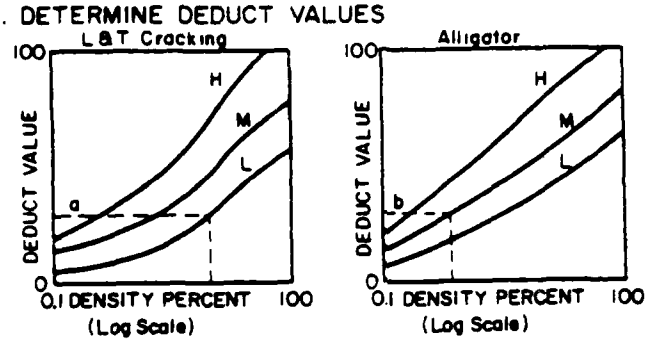
Fig 3. Example Output of Report "INV"

STEP 1 DIVIDE PAVEMENT SECTION INTO SAMPLE UNITS

STEP 2. INSPECT SAMPLE UNITS. DETERMINE DISTRESS TYPES AND SEVERITY LEVELS AND MEASURE DENSITY.

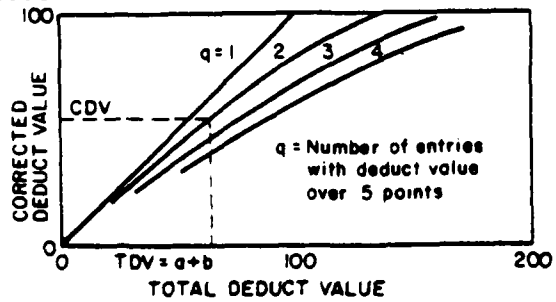



STEP 3. DETERMINE DEDUCT VALUES




STEP 4. COMPUTE TOTAL DEDUCT VALUE (TDV) a+b

STEP 5. ADJUST TOTAL DEDUCT VALUE




STEP 6. COMPUTE PAVEMENT CONDITION INDEX (PCI) 100-CDV FOR EACH SAMPLE UNIT INSPECTED

STEP 7. COMPUTE PCI OF ENTIRE SECTION (AVERAGE PCI'S OF SAMPLE UNITS).

STEP 8. DETERMINE PAVEMENT CONDITION RATING OF SECTION

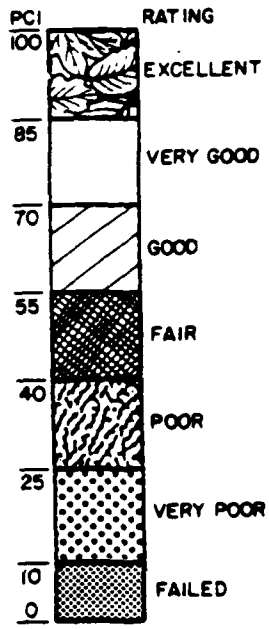



Fig 4. Steps for Determining PCI of a Pavement Section

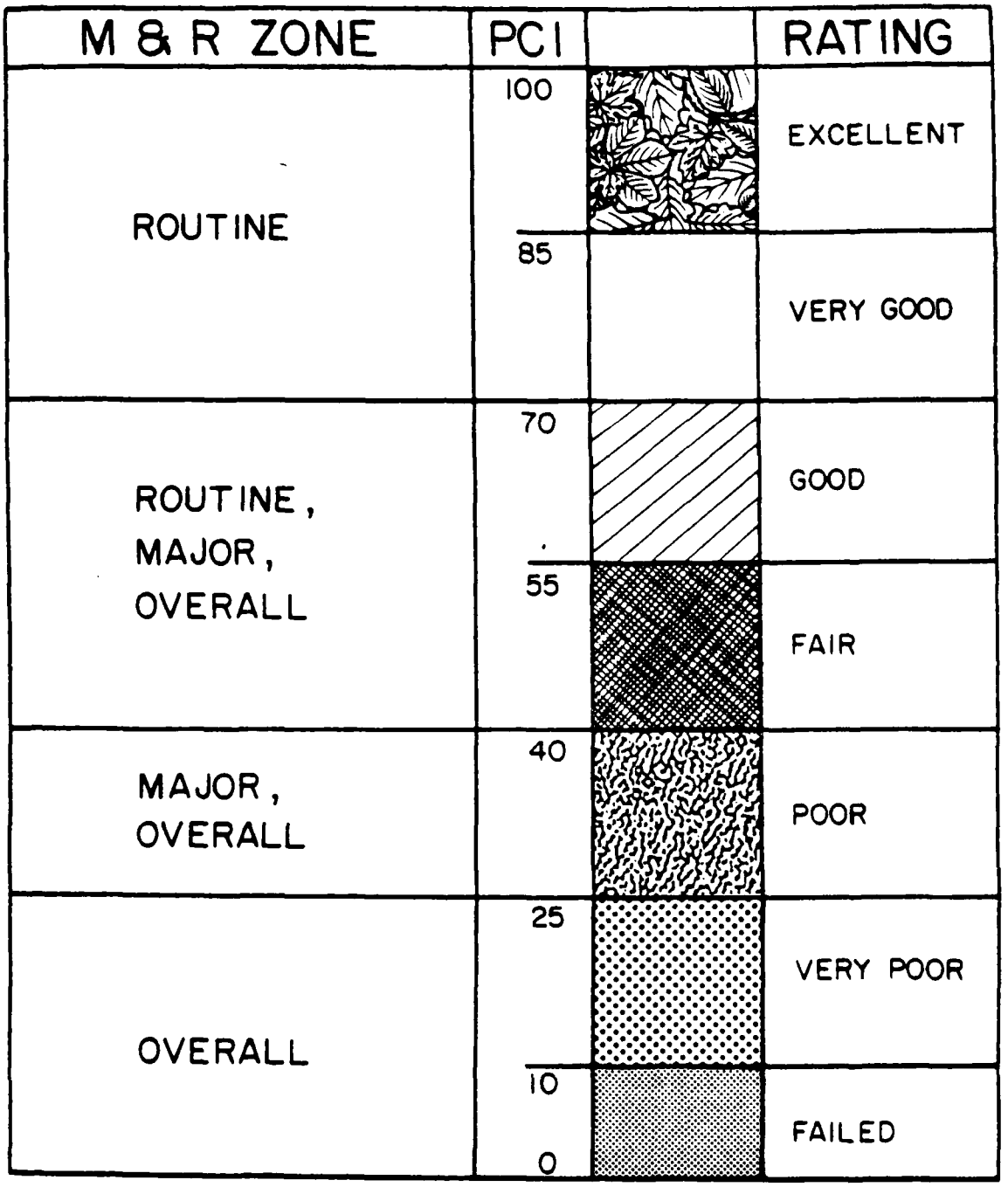



Fig 5. Correlation of M&R Zones With PCI and Condition Rating for Airfield Pavements

REPORT DATE- 09/28/81 PAVEMENT INSPECTION

BRANCH NAME - WASHINGTON NORTH SECTION LENGTH - 2307 LF
BRANCH NUMBER - IWASN SECTION WIDTH - 24 LF
SECTION NUMBER - 04 SECTION AREA - 6340 SY

INSPECTION DATE - 11/06/79 PCI= 76 RATING= VERY GOOD
CONDITION- RIDING-C2 SAFETY-C1 DRAINAGE-C1 SHOULDERS-C1 OVERALL-C1

TOTAL NUMBER OF SAMPLES IN SECTION= 24
NUMBER OF SAMPLES SURVEYED= 11
RECOMMENDED SAMPLES TO BE SURVEYED= 17
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED= 15.3

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION-

| DISTRESS TYPE | SEVERITY | QUANTITY | DENSITY-PCT | DEDUCT-VALUE |
|---|---|---|---|---|
| ALLIGATOR CR | MEDIUM | 592 SF | 1.03 | 21.4 |
| DEPRESSION | LOW | 5 SF | 0.00 | 4.0 |
| EDGE CR | HIGH | 8 LF | 0.01 | 7.4 |
| EDGE CR | LOW | 13 LF | 0.02 | 0.2 |
| EDGE CR | MEDIUM | 30 LF | 0.05 | 4.0 |
| JT REFLECT CR | HIGH | 74 LF | 0.12 | 2.6 |
| JT REFLECT CR | LOW | 128 LF | 0.22 | 0.0 |
| JT REFLECT CR | MEDIUM | 278 LF | 0.48 | 3.8 |
| LANE/SHLDR DROP | LOW | 49 LF | 0.08 | 2.0 |
| LANE/SHLDR DROP | MEDIUM | 25 LF | 0.04 | 4.0 |
| LONG/TRANS CR | LOW | 512 LF | 0.89 | 1.6 |
| PATCH/UTIL CUT | LOW | 192 SF | 0.33 | 0.8 |
| RR CROSSING | LOW | 270 SF | 0.47 | 2.0 |
| RUTTING | LOW | 150 SF | 0.26 | 2.0 |
| RUTTING | MEDIUM | 72 SF | 0.12 | 4.6 |

Fig 6. Example Output of Report "INSPECT"

REPORT DATE- 09/28/81 PCI REPORT

| BRANCH NUMBER | BRANCH USE | SECTION NUMBER | PCI | RATING | SURFACE TYPE | SECTION AREA/SY | PAVEMENT RANK |
|---|---|---|---|---|---|---|---|
| PBENE | PARKING | 01 | 10 | FAILED | AC | 440 | SECONDARY |
| | 12/04/79 | [FROM] PARKING AREA | | | [TO] | BLDG 1002 | |
| PBENE | PARKING | 03 | 10 | FAILED | AC | 440 | SECONDARY |
| | 12/04/79 | [FROM] PARKING AREA NR BLD | | | [TO] | G 1001 | |
| PSTER | PARKING | 03 | 13 | VERY POOR | PCC | 868 | TERTIARY |
| | 10/17/79 | [FROM] PARKING LOT | | | [TO] | BLDG 515 | |
| PBENE | PARKING | 02 | 18 | VERY POOR | AC | 440 | SECONDARY |
| | 12/04/79 | [FROM] PARKING AREA NR BLD | | | [TO] | G 1004 | |
| IBACK | ROADWAY | 01 | 21 | VERY POOR | AC | 5155 | TERTIARY |
| | 02/11/81 | [FROM] E EDGE HARRISON RD | | | [TO] | W EDGE MULBRY | IS RD |
| PBENE | PARKING | 04 | 25 | VERY POOR | AC | 440 | SECONDARY |
| | 12/04/79 | [FROM] PARKING AREA NR BLD | | | [TO] | G 1005 | |
| PCOND | PARKING | 01 | 25 | VERY POOR | PCC | 550 | SECONDARY |

Fig 7. Example Output of Report "PCI"

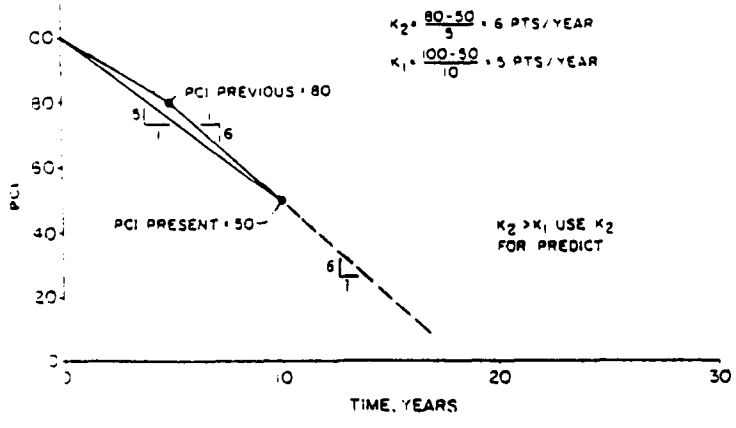
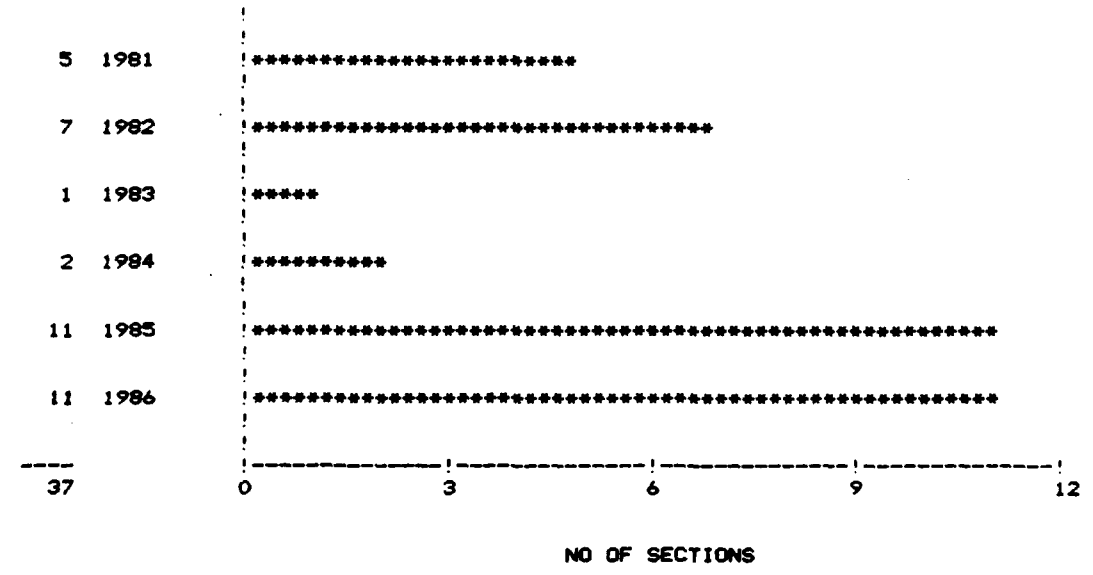



Fig 8. Example Case of PCI Prediction When PCI Was Previously Determined

INSPECTION SCHEDULE REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC
FAMILY HOUSING: B




TOTAL NO. OF SECTION: 37
SECT. NOT NEEDING REPAIR: 0
NO. OF MISSING VALUE: 1

Fig 9. Example Output of Report "SCHED"

INSPECTION SCHEDULE REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC
FAMILY HOUSING: B

LIST OF CASES IN
INSPECTION SCHEDULE REPORT

FY TO INSPECT : 1981 NO. OF SECTIONS : 5

| BRANCH NUMBER | BRANCH USE | SECT. NO. | PAVE. RANK | SUT | SEC AREA | FROM | TO |
|---|---|---|---|---|---|---|---|
| ILEEB | ROADWAY | 05 | P | AC | 7688 | W'LY SIDE ANDERSON | HINES CIR |
| IMULB | ROADWAY | 02 | P | AC | 12551 | N EDGE WILSON AVE | ENTR PINES GOLF CLB |
| IWASN | ROADWAY | 02 | P | AC | 6651 | CL MADISON AVE | N'LY SIDE HINES CIR |
| IWASN | ROADWAY | 03 | P | AC | 4000 | S'LY SIDE HINES CIR | CENTER OF SOMERVELL |
| IWASN | ROADWAY | 04 | P | AC | 6340 | CENTER OF SOMERVELL | N'LY EDGE TAYLOR |

FY TO INSPECT : 1982 NO. OF SECTIONS : 7

| BRANCH NUMBER | BRANCH USE | SECT. NO. | PAVE. RANK | SUT | SEC AREA | FROM | TO |
|---|---|---|---|---|---|---|---|
| ILEEB | ROADWAY | 02 | P | AC | 2493 | W'LY EDGE TAYLOR | CENTER KERR ROAD |
| IMADI | ROADWAY | 01 | P | AC | 823 | E'LY EDGE WASH SO | W'LY EDGE WASH NO |
| IPERS | ROADWAY | 03 | P | AC | 1917 | S'LY SIDE HAGOOD ST | CL WILSON AVE |
| IWASN | ROADWAY | 01 | P | AC | 4007 | ROUTE 105 | CL MADISON AVE |
| IWASS | ROADWAY | 01 | P | AC | 2999 | ROUTE 105 | BUS STA ENTRANCE |
| IWASS | ROADWAY | 06 | P | AC | 978 | CENTER DARCY PL | S'LY SIDE SHEPPARD |
| IWASS | ROADWAY | 07 | P | AC | 5148 | S'LY SIDE SHEPPARD | N'LY EDGE TAYLOR |

FY TO INSPECT : 1983 NO. OF SECTIONS : 1

| BRANCH NUMBER | BRANCH USE | SECT. NO. | PAVE. RANK | SUT | SEC AREA | FROM | TO |
|---|---|---|---|---|---|---|---|
| IHINE | ROADWAY | 01 | P | AC | 6586 | END LEE 05 | CCW TO END LEE 05 |

FY TO INSPECT : 1984 NO. OF SECTIONS : 2

| BRANCH NUMBER | BRANCH USE | SECT. NO. | PAVE. RANK | SUT | SEC AREA | FROM | TO |
|---|---|---|---|---|---|---|---|
| IMADI | ROADWAY | 06 | P | AC | 1781 | N EDGE PATTON | END AC PAVEMENT |
| ITAYL | ROADWAY | 02 | P | AC | 11806 | 50 FT W OF HARRISON | W'LY SIDE WASH SO |

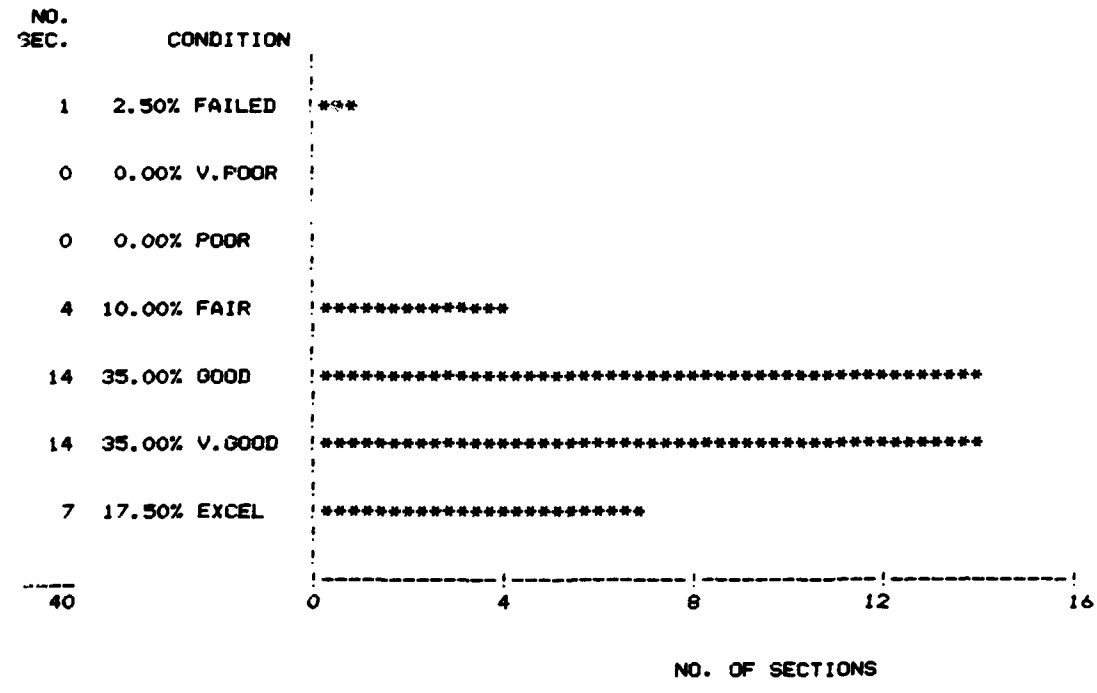
Fig 9. Example Output of Report "SCHED" (Continued)

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

YR= 1982 1




TOTAL NO. OF SECTION: 40
AVERAGE PCI: 70
NO. OF MISSING VALUE: 1

Fig 10. Example Output of Report "FREQ" for January 1982

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

LIST OF SECTIONS IN
PCI FREQ REPORT
YR= 1982/01

| BRANCH NUMBER | BRANCH USE | SECT. NO. | CUR PCI | PRO PCI | ---FROM--- | ---TO--- |
|---|---|---|---|---|---|---|
| IWASN | ROADWAY | 04 | 29 | 0 | CENTER OF SOMERVELL | N'LY EDGE TAYLOR |
| ILEEB | ROADWAY | 05 | 65 | 47 | W'LY SIDE ANDERSON | HINES CIR |
| IWASN | ROADWAY | 03 | 64 | 49 | S'LY SIDE HINES CIR | CENTER OF SOMERVELL |
| IMULB | ROADWAY | 02 | 57 | 52 | N EDGE WILSON AVE | ENTR PINES GOLF CLB |
| IWASN | ROADWAY | 02 | 68 | 52 | CL MADISON AVE | N'LY SIDE HINES CIR |
| IWASS | ROADWAY | 01 | 82 | 56 | ROUTE 105 | BUS STA ENTRANCE |
| IWASN | ROADWAY | 01 | 72 | 59 | ROUTE 105 | CL MADISON AVE |
| IPERS | ROADWAY | 03 | 66 | 59 | S'LY SIDE HAGOOD ST | CL WILSON AVE |
| IWASS | ROADWAY | 06 | 72 | 59 | CENTER DARCY PL | S'LY SIDE SHEPPARD |
| IWASS | ROADWAY | 07 | 74 | 61 | S'LY SIDE SHEPPARD | N'LY EDGE TAYLOR |
| ILEEB | ROADWAY | 02 | 76 | 63 | W'LY EDGE TAYLOR | CENTER KERR ROAD |
| IMADI | ROADWAY | 01 | 87 | 65 | E'LY EDGE WASH SO | W'LY EDGE WASH NO |
| ITAYL | ROADWAY | 02 | 71 | 65 | 50 FT W OF HARRISON | W'LY SIDE WASH SO |
| IMADI | ROADWAY | 07 | 69 | 66 | END AC PAVEMENT | N EDGE TAYLOR AVE |
| ITAYL | ROADWAY | 04 | 70 | 68 | E'LY SIDE WASH NO | END CONC PAVEMENT |
| IHINE | ROADWAY | 01 | 88 | 69 | END LEE 05 | CCW TO END LEE 05 |
| IMADI | ROADWAY | 06 | 77 | 69 | N EDGE PATTON | END AC PAVEMENT |
| IPERS | ROADWAY | 02 | 74 | 70 | ENTRANCE BLDG 1702 | S'LY SIDE HAGOOD ST |
| IMULB | ROADWAY | 05 | 73 | 70 | RR BY PISTOL RANGE | 250 FT W BLDG 3905 |
| IMULB | ROADWAY | 01 | 76 | 73 | S EDGE TAYLOR AVE | N EDGE WILSON AVE |
| IMADI | ROADWAY | 03 | 81 | 74 | N'LY SIDE JEFFERSON | N'LY SIDE REINECKER |
| IMULB | ROADWAY | 03 | 78 | 75 | ENTR PINES GOLF CLB | RR AT PISTOL RANGE |
| IWASS | ROADWAY | 04 | 82 | 75 | CENTER DILLON CIR | N'LY SIDE HINES CIR |
| IMADI | ROADWAY | 02 | 83 | 76 | E'LY EDGE WASH NO | N'LY SIDE JEFFERSON |
| IWASS | ROADWAY | 03 | 83 | 76 | N'LY EDGE MADISON | CENTER DILLON CIR |
| ILEEB | ROADWAY | 03 | 86 | 78 | CENTER KERR ROAD | W EDGE LUCAS PLACE |
| IWASS | ROADWAY | 05 | 82 | 78 | S'LY EDGE HINES CIR | CENTER DARCY PL |
| ILEEB | ROADWAY | 06 | 86 | 79 | E SIDE HINES CIR | W'LY EDGE MADISON |
| ITAYL | ROADWAY | 03 | 88 | 81 | W'LY SIDE WASH SO | E'LY SIDE WASH NO |
| IMADI | ROADWAY | 04 | 86 | 81 | N'LY SIDE REINECKER | CENTER LEE BLVD |
| ILEEB | ROADWAY | 04 | 89 | 83 | W'LY SIDE LUCAS PL | W'LY SIDE ANDERSON |
| IPERS | ROADWAY | 01 | 92 | 84 | E'LY EDGE MADISON | ENTRANCE BLDG 1702 |
| IPERS | ROADWAY | 04 | 86 | 84 | CL WILSON AVE | OFFICERS CLUB |
| IMADI | ROADWAY | 05 | 90 | 86 | CENTER LEE BLVD | N'LY EDGE PATTON AV |
| ITAYL | ROADWAY | 01 | 92 | 87 | S'LY EDGE LEE BLVD | 50 FT W OF HARRISON |
| IWILS | ROADWAY | 02 | 92 | 89 | E'LY EDGE MULB IS | CENTER OF IRWIN ST |
| IEUST | ROADWAY | 01 | 96 | 91 | S EDGE WARWICK BLVD | W EDGE WASH BLVD SO |
| IWASS | ROADWAY | 02 | 94 | 91 | BUS STA ENTRANCE | N'LY SIDE MADISON |
| ITAYL | ROADWAY | 05 | 93 | 91 | BEGIN ASPH PAVEMENT | N'LY EDGE WILSON AV |
| IWILS | ROADWAY | 03 | 96 | 94 | CENTER OF IRWIN ST | W'LY EDGE PERSHING |

TOTAL NO. OF SECTION: 40
AVERAGE PCI: 70
NO. OF MISSING VALUE: 1

Fig 10. Example Output of Report "FREQ" for January 1982 (Continued)

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

YR= 1983/01

| NO. SEC. | CONDITION | |
|---|---|---|
| 1 | 2.50% FAILED | *** |
| 0 | 0.00% V.POOR | |
| 1 | 2.50% POOR | *** |
| 7 | 17.50% FAIR | ********** |
| 10 | 25.00% GOOD | ********** |
| 15 | 37.50% V.GOOD | ********** |
| 6 | 15.00% EXCEL | ********** |
| 40 | | 0 4 8 12 16 |

NO. OF SECTIONS

TOTAL NO. OF SECTION: 40
AVERAGE PCI: 67
NO. OF MISSING VALUE: 1

Fig 11. Example Output of Report "FREQ" for January 1983

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

LIST OF SECTIONS IN
PCI FREQ REPORT
YR= 1983/01

| BRANCH NUMBER | BRANCH USE | SECT. NO. | CUR PCI | PRO PCI | ---FROM--- | ---TO--- |
|---|---|---|---|---|---|---|
| IWASN | ROADWAY | 04 | 29 | 0 | CENTER OF SOMERVELL | N'LY EDGE TAYLOR |
| ILEEB | ROADWAY | 05 | 65 | 39 | W'LY SIDE ANDERSON | HINES CIR |
| IWASN | ROADWAY | 03 | 64 | 42 | S'LY SIDE HINES CIR | CENTER OF SOMERVELL |
| IWASS | ROADWAY | 01 | 82 | 44 | ROUTE 105 | BUS STA ENTRANCE |
| IWASN | ROADWAY | 02 | 68 | 45 | CL MADISON AVE | N'LY SIDE HINES CIR |
| IMULB | ROADWAY | 02 | 57 | 50 | N EDGE WILSON AVE | ENTR PINES GOLF CLB |
| IWASN | ROADWAY | 01 | 72 | 52 | ROUTE 105 | CL MADISON AVE |
| IWASS | ROADWAY | 06 | 72 | 52 | CENTER DARCY PL | S'LY SIDE SHEPPARD |
| IMADI | ROADWAY | 01 | 87 | 55 | E'LY EDGE WASH SO | W'LY EDGE WASH NO |
| IWASS | ROADWAY | 07 | 74 | 56 | S'LY SIDE SHEPPARD | N'LY EDGE TAYLOR |
| IPERS | ROADWAY | 03 | 66 | 57 | S'LY SIDE HAGOOD ST | CL WILSON AVE |
| ILEEB | ROADWAY | 02 | 76 | 58 | W'LY EDGE TAYLOR | CENTER KERR ROAD |
| IHINE | ROADWAY | 01 | 88 | 61 | END LEE 05 | CCW TO END LEE 05 |
| ITAYL | ROADWAY | 02 | 71 | 63 | 50 FT W OF HARRISON | W'LY SIDE WASH SO |
| IMADI | ROADWAY | 06 | 77 | 65 | N EDGE PATTON | END AC PAVEMENT |
| IMADI | ROADWAY | 07 | 69 | 65 | END AC PAVEMENT | N EDGE TAYLOR AVE |
| ITAYL | ROADWAY | 04 | 70 | 67 | E'LY SIDE WASH NO | END CONC PAVEMENT |
| IPERS | ROADWAY | 02 | 74 | 68 | ENTRANCE BLDG 1702 | S'LY SIDE HAGOOD ST |
| IMULB | ROADWAY | 05 | 73 | 68 | RR BY PISTOL RANGE | 250 FT W BLDG 3905 |
| IMADI | ROADWAY | 03 | 81 | 71 | N'LY SIDE JEFFERSON | N'LY SIDE REINECKER |
| IWASS | ROADWAY | 04 | 82 | 71 | CENTER DILLON CIR | N'LY SIDE HINES CIR |
| IMULB | ROADWAY | 01 | 76 | 72 | S EDGE TAYLOR AVE | N EDGE WILSON AVE |
| IWASS | ROADWAY | 03 | 83 | 73 | N'LY EDGE MADISON | CENTER DILLON CIR |
| IMADI | ROADWAY | 02 | 83 | 74 | E'LY EDGE WASH NO | N'LY SIDE JEFFERSON |
| IMULB | ROADWAY | 03 | 78 | 74 | ENTR PINES GOLF CLB | RR AT PISTOL RANGE |
| ILEEB | ROADWAY | 03 | 86 | 75 | CENTER KERR ROAD | W EDGE LUCAS PLACE |
| ILEEB | ROADWAY | 06 | 86 | 75 | E SIDE HINES CIR | W'LY EDGE MADISON |
| IWASS | ROADWAY | 05 | 82 | 76 | S'LY EDGE HINES CIR | CENTER DARCY PL |
| IMADI | ROADWAY | 04 | 86 | 78 | N'LY SIDE REINECKER | CENTER LEE BLVD |
| ITAYL | ROADWAY | 03 | 88 | 79 | W'LY SIDE WASH SO | E'LY SIDE WASH NO |
| IPERS | ROADWAY | 01 | 92 | 80 | E'LY EDGE MADISON | ENTRANCE BLDG 1702 |
| ILEEB | ROADWAY | 04 | 89 | 80 | W'LY SIDE LUCAS PL | W'LY SIDE ANDERSON |
| IPERS | ROADWAY | 04 | 86 | 83 | CL WILSON AVE | OFFICERS CLUB |
| IMADI | ROADWAY | 05 | 90 | 84 | CENTER LEE BLVD | N'LY EDGE PATTON AV |
| ITAYL | ROADWAY | 01 | 92 | 86 | S'LY EDGE LEE BLVD | 50 FT W OF HARRISON |
| IEUST | ROADWAY | 01 | 96 | 88 | S EDGE WARWICK BLVD | W EDGE WASH BLVD SO |
| IWILS | ROADWAY | 02 | 92 | 88 | E'LY EDGE MULB IS | CENTER OF IRWIN ST |
| IWASS | ROADWAY | 02 | 94 | 90 | BUS STA ENTRANCE | N'LY SIDE MADISON |
| ITAYL | ROADWAY | 05 | 93 | 91 | BEGIN ASPH PAVEMENT | N'LY EDGE WILSON AV |
| IWILS | ROADWAY | 03 | 96 | 94 | CENTER OF IRWIN ST | W'LY EDGE PERSHING |

TOTAL NO. OF SECTION: 40
AVERAGE PCI: 67
NO. OF MISSING VALUE: 1

Fig 11. Example Output of Report "FREQ" for January 1983 (Continued)

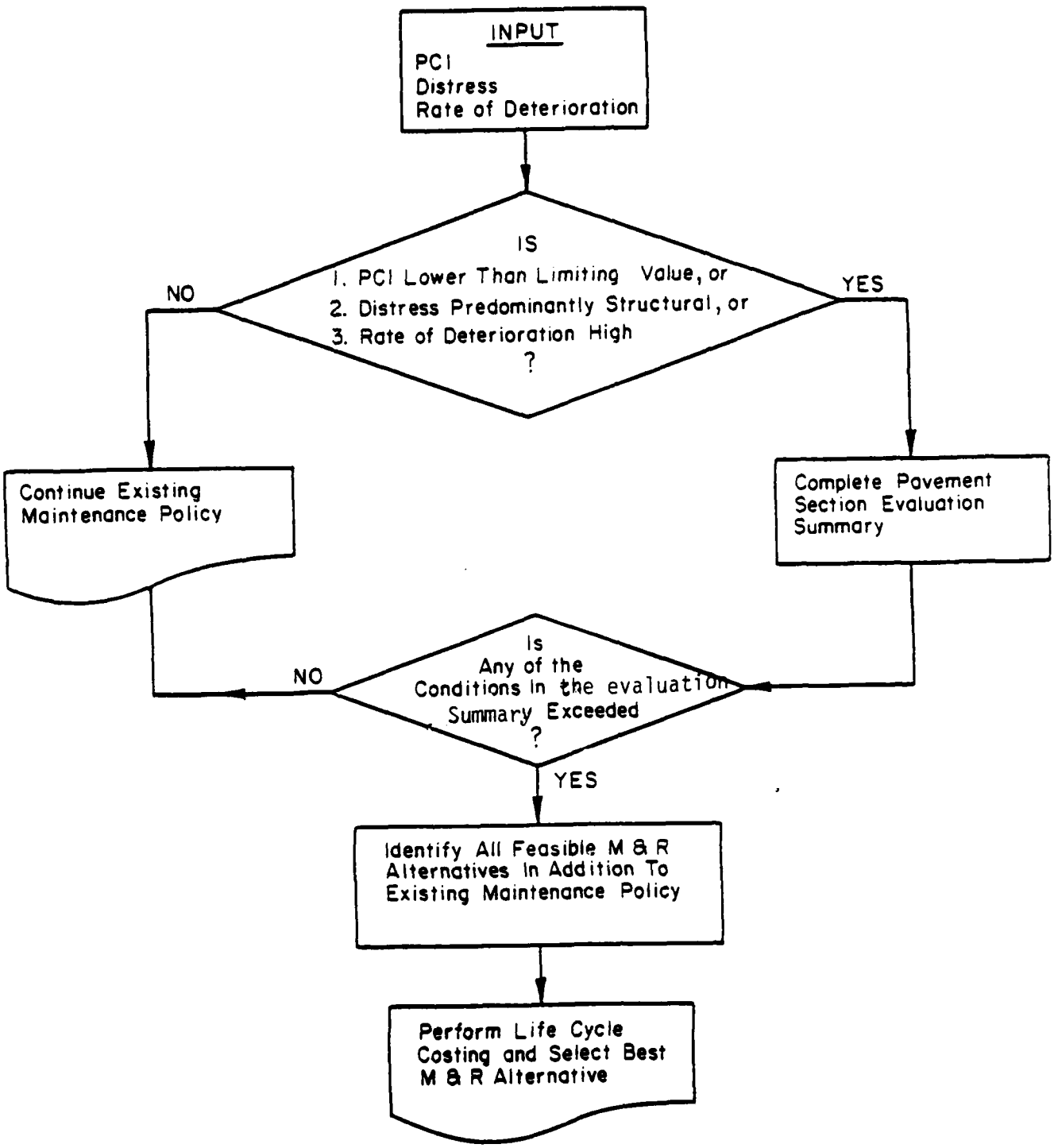



Fig 12. Flow Diagram of the Decision Process for Determining M&R Needs

CONDITION HISTORY

REPORT DATE: 81/09/28.

BRANCH NAME: WASHINGTON NORTH
BRANCH USE: ROADWAY
SECTION NUMBER: 04
PAVEMENT RANK: PRIMARY
SURFACE TYPE: AC

| | DATE | PCI |
|---|---|---|
| CONST/OVERLAY | 75/06 | 100 |
| INSP | 79/11 | 76 |
| INSP | 81/02 | 29 |
| PRED | 1981 | 0 |

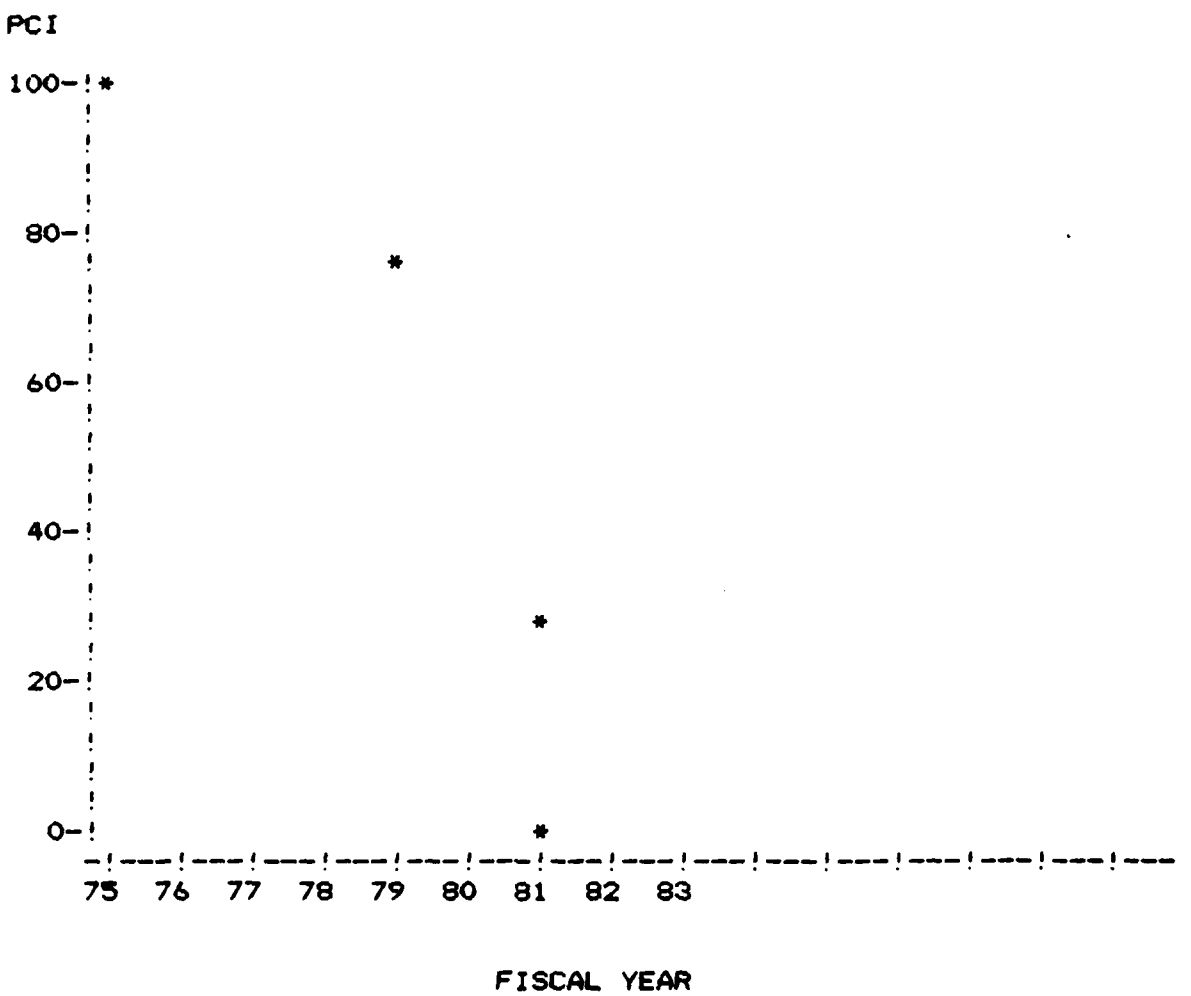



Fig 13. Example Output of Report "CNDHIST"

REPORT DATE - 81/10/05.

MAINTENANCE AND REPAIR GUIDELINES

BRANCH NAME - WASHINGTON NORTH
BRANCH NMBR - IWASN
SECTION NMBR - 04

SECTION LENGTH - 2307 LF
SECTION WIDTH - 24 LF
SECTION AREA - 6340 SY

INSPECTION DATE - 02/11/81

SECTION PCI - 29

| DISTRESS TYPE | DIS SEV | DIST-QTY WORK-QTY | WORK TYPE | MATL CODE | LABOR HOURS | LABOR COST$ | MAT'L COST$ | EQUIP COST$ | TOTAL COST$ |
|---|---|---|---|---|---|---|---|---|---|
| ALLIGATOR CR | M | 1682 SF | | | | | | | |
| | | 1682 SF | SHALLOW PATCH | 120 | 841.0 | 10092 | 336 | 1867 | 13136 |
| LONG/TRANS CR | M | 975 LF | | | | | | | |
| | | 975 LF | CRACK FILLING | 171 | 0.0 | 0 | 0 | 0 | 633 |
| | | | OVERLAY | 120 | | | | | 19020 |
| | | | | TOTAL | 841.0 | 10092 | 336 | 1867 | 32789 |

Fig 14. Example Output of Report "MRG"

```
 CURRENT VALUES ARE AS FOLLOWS :=
  1  PCI :=  29
  2  LOCAL VARIATION(Y/N)        := N
  3  SYSTEMATIC VARIATION(Y,N) := N
  4  SHORT TERM RATE OF DETERIORATION(L,N,H):= H
  5  LONG TERM RATE OF DETERIORATION(L,N,H) := H
  6  MAJOR SOURCE OF DISTRESS(LOAD,CLIMATE) := L
  7  LOAD CARRYING DEFICIENCY(Y,N) := Y
  8  SURFACE ROUGHNESS(L,M,H)       := L
  9  SKID/HYDROPLANING PROBLEMS(L,M,H) := L
 10  PREVIOUS MAINTENANCE(L,N,H)        := N
 SELECT(A-D) :=
D>C

 DATE := 29 SEP 81          FEASIBLE M&R ALTERNATIVES

 BASE := M Y SHAHIN                    FEATID := WASH      PCI:=  29
 FEATNM := WASHINGTON BLVD             M&R REPAIR ZONE := MAJOR-OVERALL

          ***** RECOMMENDED MAINTENANCE ALTERNATIVES *****

           1 :=  RECONSTRUCTION
           2 :=  OVERLAY STRUCTURAL AC
           4 :=  OVERLAY PCC
          11 :=  RECYCLE STRUCTURE

          *** END ***
```

Fig 15. Example Output of Report "EVAL"

| | M&R ACTIVITY DESC | YEAR | COST | TIME-SPACING |
|---|---|---|---|---|
| 1 | 6 IN GRAN.$10/TON | 1982 | 32630.00 | 0 |
| 2 | PRIME .$.27/SY | 1982 | 3802.00 | 0 |
| 3 | 4 IN AC .$30/TON | 1982 | 38704.00 | 0 |
| 4 | REP 2 %.1.5 INT COST | 1987 | 3754.00 | 5 |
| 5 | PATCH & MAINT..05/SY | 1988 | 704.00 | 1 |
| 6 | SURF SEAL .$.1/SY | 1989 | 1408.00 | 0 |
| 7 | SURF SEAL .$.1/SY | 1996 | 1408.00 | 0 |

Fig 16. Typical Input to Economic Analysis Program

DATE:= 81/09/28. PROJECTED COST ANALYSIS (DETAIL)

SECTION ID:=TW

ALTERNATIVE:= 4N IN AC/6 IN GRAN SECTION AREA(S.Y.):= 14080.0
LIFE OF ALTERNATIVE:= 20 INTEREST RATE:= 10.0 INFLATION RATE:= 0.0

| M&R ACTIVITY | YEAR | COST($) | PRESENT VALUE($) |
|---|---|---|---|
| 6 IN GRAN,$10/TON | 1982 | 32630.00 | 32630.00 |
| PRIME,$.27/SY | 1982 | 3802.00 | 3802.00 |
| IN AC,$30/TON | 1982 | 88704.00 | 88704.00 |
| | TOTAL:= | 125136.00 | 125136.00 |
| REP 2%,1.5 INT COST | 1987 | 3754.00 | 2330.94 |
| PATCH & MAINT.,05/SY | 1988 | 704.00 | 397.39 |
| PATCH & MAINT.,05/SY | 1989 | 704.00 | 361.26 |
| SURF SEAL,$.1/SY | 1989 | 1408.00 | 722.53 |
| | TOTAL:= | 2112.00 | 1083.79 |
| PATCH & MAINT.,05/SY | 1990 | 704.00 | 328.42 |
| PATCH & MAINT.,05/SY | 1991 | 704.00 | 298.56 |
| REP 2%,1.5 INT COST | 1992 | 3754.00 | 1447.33 |
| PATCH & MAINT.,05/SY | 1992 | 704.00 | 271.42 |
| | TOTAL:= | 4458.00 | 1718.75 |
| PATCH & MAINT.,05/SY | 1993 | 704.00 | 246.75 |
| PATCH & MAINT.,05/SY | 1994 | 704.00 | 224.32 |
| PATCH & MAINT.,05/SY | 1995 | 704.00 | 203.92 |
| PATCH & MAINT.,05/SY | 1996 | 704.00 | 185.39 |
| SURF SEAL,$.1/SY | 1996 | 1408.00 | 370.77 |
| | TOTAL:= | 2112.00 | 556.16 |
| REP 2%,1.5 INT COST | 1997 | 3754.00 | 898.68 |
| PATCH & MAINT.,05/SY | 1997 | 704.00 | 168.53 |
| | TOTAL:= | 4458.00 | 1067.21 |
| PATCH & MAINT.,05/SY | 1998 | 704.00 | 153.21 |
| PATCH & MAINT.,05/SY | 1999 | 704.00 | 139.28 |
| PATCH & MAINT.,05/SY | 2000 | 704.00 | 126.62 |
| PATCH & MAINT.,05/SY | 2001 | 704.00 | 115.11 |

INITIAL COST($):= 125136.00
PRESENT VALUE($):= 134126.43
EQUIVALENT UNIFORM ANNUAL COST($):= 15754.44
EUAC PER SQ. YD. ($):= 1.12

---------- END OF REPORT ----------

Fig 17. Economic Analysis Output for Input Shown in Fig 15

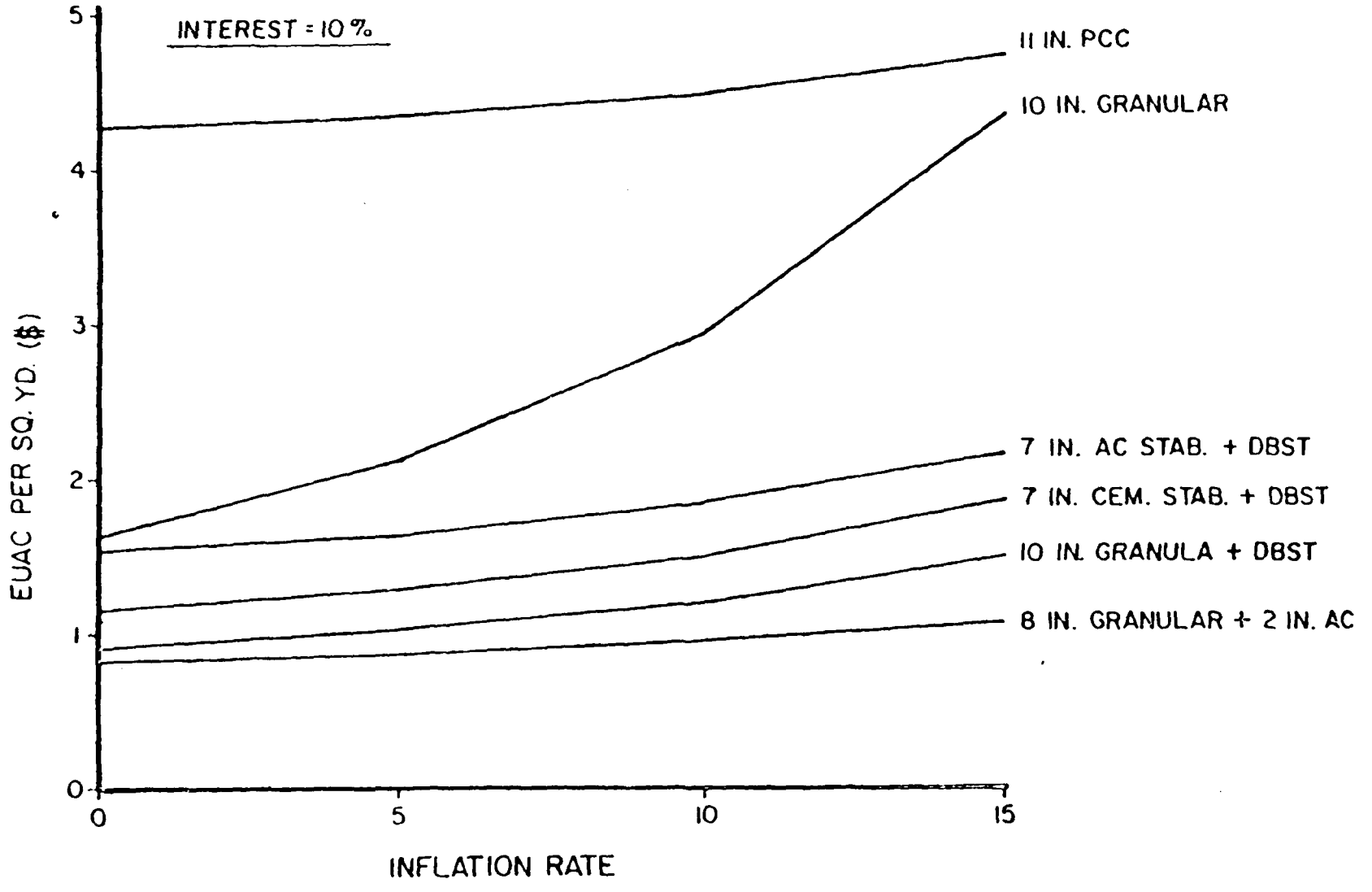
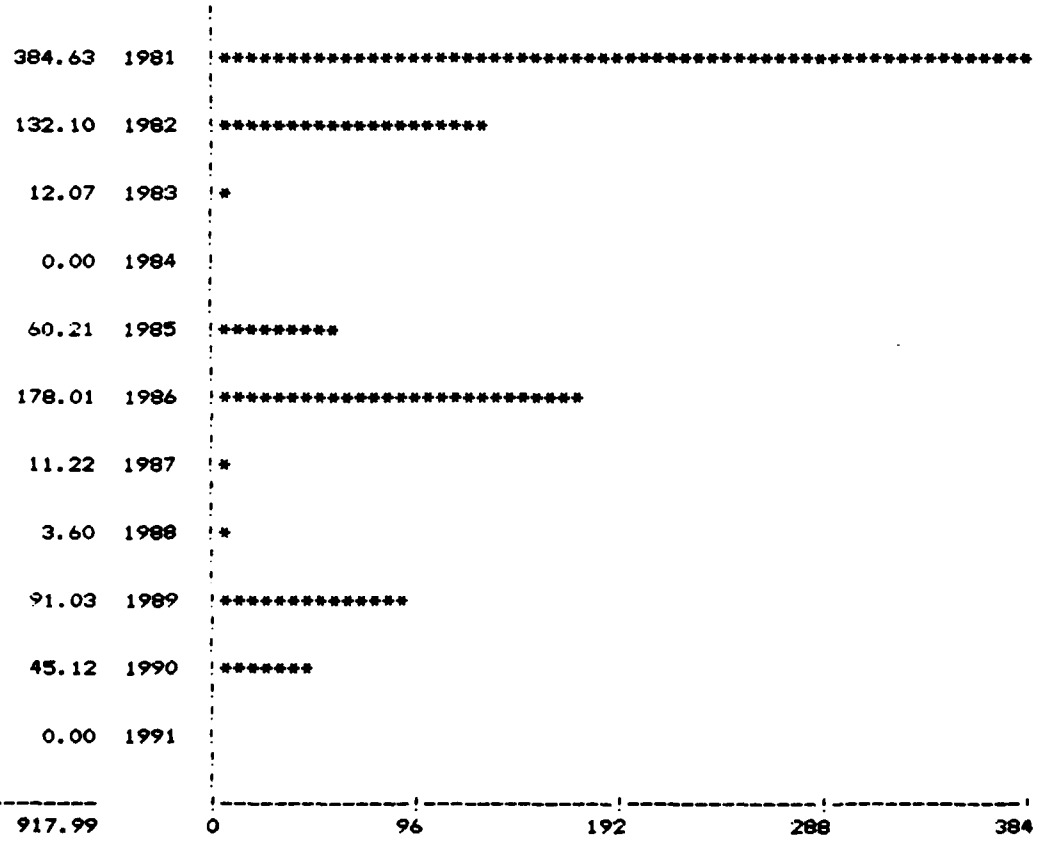



Fig 18. Example Equivalent Uniform Annual Cost (EUAC) per SY for Various Alternatives

BUDGET PLANNING REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC
INFLATION RATE: 10.00
FAMILY HOUSING: B




TOTAL NO. OF SECTION: 28
SECT. NOT NEEDING REPAIR: 9
NO. OF MISSING VALUE: 1

Fig 19. Example Output of Report "BUDPLAN"

TABLE 1. MAINTENANCE GUIDELINES FOR ASPHALT PAVEMENT DISTRESSES

| Distress Type / M&R Method | | Do Nothing | Crack Seal | Partial Depth Patch | Full Depth Patch | Skin Patch | Pothole Filling | Apply Heat & Roll Sand | Apply Surface Seal Emulsion | Apply Rejuvenation | Apply Aggregate Seal Coat | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Alligator Cracking | | | M,H | M,H | | | | L | L | | |
| 2 | Bleeding | L | | | | | | L,M,H | | | | |
| 3 | Block Cracking | L | L,M,H | | | | | | | L | L,M | |
| 4 | Bumps & Sags | L | | M,H | M,H | M,H | | | | | | |
| 5 | Corrugation | L | | M,H | M,H | | | | | | | |
| 6 | Depression | L | | M,H | M,H | M,H | | | | | | |
| 7 | Edge Cracking | L | L,M | M,H | M,H | | | | | | | If predominant, apply shoulder seal, e.g., aggregate seal coat |
| 8 | Joint Reflective Cracking | L | L,M,H | H | | | | | | | | |
| 9 | Lane/ Shoulder Drop Off | L | | | | | | | | | | If predominant, level off shoulder and apply aggregate seal coat |
| 10 | Longitudinal Transverse Cracking | L | L,M,H | H | | | | | L | L | L,M | |
| 11 | Patching & Utility Cut | L | M | H* | H* | | | | | | | *Replace patch |
| 12 | Polished Aggregate | A | | | | | | | | | A | |
| 13 | Potholes | | | L | L,M,H | | L,M,H | | | | | |
| 14 | Railroad Crossing | L | | | | L,M,H | | | | | | |
| 15 | Rutting | L | | L,M,H | M,H | L,M,H | | | | | | |
| 16 | Shoving | L | | M,H | | | | | | | | |
| 17 | Slippage Cracking | L | L | M,H | | | | | | | | |
| 18 | Swell | L | | | M,H | | | | | | | |
| 19 | Weathering & Raveling | L | | H | | | | | L,M | L | M,H | |

Note: L = low severity; M = medium severity; H = high severity; A = has only one severity level.

# ECONOMIC ANALYSIS OF FIELD IMPLEMENTING THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

## INTRODUCTION

PAVER is an automated pavement management system that provides the user with practical management tools including: data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning. PAVER uses the System 2000 (ref 1) as the data base manager. This system and other "interface" programs allow the user to generate preformatted reports of critical information. This information allows objective input to the decision-making process. A complete description of PAVER is provided in refs 2 and 3.

This paper presents an economic analysis of PAVER based on a full-scale field Prototype Evaluation Test (PET) at a U.S. military installation. The official PET monitoring was started on 16 Feb 81 and ran through 15 Jun 81. The military installation's pavements are equivalent to 212 lane miles. The test was monitored by 21 pavement experts from the U.S. Army Corps of Engineers, Major Command Headquarters, and several installations. Two analyses are presented; one based on the PET data only and the other based on the PET data and estimates.

## DESCRIPTION OF THE PET

The PET was started by letting a lump sum contract in September 1979 to collect all the necessary information to create a full data base on the military installation's pavements. This contract included the following items:

(1) Divide the pavement network into branches and sections and provide maps documenting the division.

(2) Perform a pavement condition survey on all paved areas: roadways, parking areas, motorpools, helipads, runways, taxiways, and aprons.

(3) Collect pavement structure information from as-built drawings and core borings.

(4) Collect all information regarding drainage, secondary structures, and shoulders.

(5) Input data into data base and verify the input.

The total contract price of the data collection was $91,437. A breakdown of the contract cost and the amount of pavement surveyed is shown in Tables 1A and 1B, respectively. Using the information of Table 1B, a lane mile cost of

inspection was calculated to be $306/lane mile. Based on the data shown in Table 1B, this reflects the inspection cost for a sampling rate of 51 percent.

It was learned from the PET that the initial sampling rate need not be this high for the initial implementation to provide adequate information on pavement condition. It is anticipated that a sampling rate of approximately 15 percent would be sufficient. Using this reduced sampling rate, an estimated contract cost for full-scale implementation was derived and is shown in Table 2. These values were obtained by linearly interpolating the contract prices for the 51 percent rate.

During the PET, the form shown in Figure 1 was used to record the computer time and man-hours associated with using PAVER and provide an estimate of the time involved in performing each task manually. A portion of the data from the returned forms is shown in Table 3. The hours recorded for M&R project development shown at the bottom of the table were estimated by the Engineering Planning Division at the installation. The 120 hours shown were used with PAVER information in planning a total of 36 projects when end of year money was available. The 480 hours is an estimate of the time to do the same work without the aid of the PAVER system. The installation personnel indicated that without the PAVER system, several projects would have had to be eliminated due to lack of time. Thus, the installation would not have been able to obligate the full amount of monies available to them.

A review of the data indicated that the principal time savings occurred in developing long range plans, budget information reports, M&R cost estimating, and economic analysis. The savings come from the extra computing power offered by PAVER that is not available under the current operating method. Projecting the totals shown in Table 3 over a 1-year period, the following totals are estimated:

(1) PAVER time: 525 man-hours/year

(2) PAVER computer time: 17,391 computer charge units (ccu's/year)

(3) Current method time: 1748 man-hours/year

The ccu's shown were incurred both interactively and through the PAVER "batch process" procedure. Interactive runs cost about $.12/ccu while the ccu cost in the batch process can vary from $.015 to $.075/ccu depending on the selected priority. To develop a weighted average cost for computer usage, the costs and percentages of use shown in Table 4 were used. The percentages of use presented in Table 4 were verified with the installation Buildings and Grounds Division Chief. The resulting average cost based on Table 4 is $.0765/ccu. The Buildings and Grounds Division Chief indicated that as they become more familiar with PAVER, they are likely to use more of the lower priority (i.e., P01) than indicated from the PET. This will result in a reduced computer cost.

The data presented in this section will be used in the economic analysis in the following sections.

## ECONOMIC ANALYSIS

### General

The economic analysis of the PAVER system and the current operating method will be developed in the following two ways:

(1) Comparison of the alternatives (i.e., the PAVER system and current method) based on the PET data projected annually. An inherent assumption in this comparison is that the activities performed during the 4 months of the PET represent normal annual operations. This comparison will be referred to from now on as the "PET Data Comparison."

(2) Comparison of the alternatives based on estimated times and costs for expected annual use. The data used for this analysis are based on Table 3 and additional input from the Chief, Buildings and Grounds at the installation. This comparison will be referred to from now on as the "Estimated Data Comparison."

The analysis method used was a present worth analysis using a life of 8 years for the PAVER system.

### Assumptions

(1) The installation was selected as an average installation so that the cost of the PET should be representative of costs to implement the system at other installations of similar size. However, the selected installation has employed a manual management system over the past years.

(2) Data processing equipment necessary to operate the automated system will be purchased by the installations (ASCII terminal and acoustical modem). Terminal cost will be distributed over the systems supported by the terminal.

(3) Data base will be maintained for all installations by a single organization. The costs of management will be split between installations for unit cost purposes.

(4) No additional employees will be needed at the installation level to operate the system.

(5) PAVER offers the user more information and procedures than currently available. These items will be considered benefits.

### Constraints

(1) The use of PAVER during the four-month PET is not necessarily proportional to a full year's use because different types of activities are required at certain times of the year. Therefore, two analyses are performed as indicated under "General" above.

(2) Time estimates of activities during the PET were made while the PAVER system was in use. Thus, a true dichotomy of tasks was not possible.

Alternative 1 - Current Operating Method

The current method of operation at the installation is a manual card file procedure. This method has been developed by the installation personnel and has been in operation for several years. The procedure basically consists of a card catalogue of pavement sections in which information on pavement structure and past major maintenance is recorded.

(1) PET Data Comparison: The costs based on PET data for the current method consisted of 582.5 man-hours (see Table 3). These hours were split between three engineers, resulting in an average hourly rate of approximately $15.00/hr. With the total hours shown in Table 3, the current method cost is calculated to be $8,737 for 4 months or approximately $26,200/year. These costs are summarized in Table 5.

(2) Estimated Data Comparison: Activities performed during a normal year have been categorized into six groups. The time and costs for these categories are shown in Table 6. The total estimated annual cost is $17,238/year. These costs are based on discussions with the Chief, Buildings and Grounds at the installation, and a breakdown of the costs in Table 3.

*Benefits - Alternative 1*

(1) Tangible Benefits: There are no tangible benefits associated with the current method of operation.

(2) Intangible Benefits: There are certain intangible benefits associated with continuing the current method of operation:

(a) The current method is a local method that is user acceptable.

(b) No sophisticated equipment is required.

These benefits, however, are particular to the test installation since most other installations have no manual system.

*Risks - Alternative 1*

If the current operating method continues, the following risks should be considered.

(1) The number of projects not funded will most likely continue to rise and the total dollar requirement for pavement maintenance will increase.

(2) No common ground of communication will be established between the installation engineers and Major Command engineers.

(3) No objective procedure for pavement rating will be established, reducing the chances for division of maintenance monies based on condition of the pavements.

(4) Continual back-up of work and inconsistent evaluation procedures will decrease pavement life.

Alternative 2 - Automated PAVER

The PAVER system was fully implemented at the installation (i.e., all paved areas were inspected). The initial inspection and data input were performed under a lump sum contract. The actual cost of this initiation along with operation costs from the PET will be considered.

(1) PET Data Comparison: The "operating" costs from the PET for PAVER, as shown in Table 3, are 175 man-hours and 5796 ccu's for computer use. The cost of a man-hour is again the average of $15.00/hour resulting in a 4-month cost of $2,628 or approximately $7,886/year. The computer cost used was $.0765/ccu as computed in the economic analysis. This yields a computer cost of $443/4 months or approximately $1330/year. This is the actual computer time cost; there are also support costs associated with computer use. These can be itemized as follows:

(a) Connect time* - $8.50/hour.

(b) Tape storage - $0.25/day.

(c) Disc storage - $22.00/1000 sectors/month.

(d) Communication line (telephone) - $29.00/month.

(e) Computer paper - $21.00/box.

(f) Equipment (terminal and modem) - $1500.00.

The computer connect time for the PET was approximately 15 hours. Based on the $8.50/hour rate, the connect time is calculated to be 129/4 months or $387/year.

Tape storage was not used during the PET so no tape charges are included for the PET analysis. No tapes were used in the PET as a matter of convenience. The present disc storage charge is $22.00/1000 sectors/month. The installation data base is approximately 700 sectors of disc space. This results in an annual charge of $1848/year.

Since the military installation Autovon telephone lines will not support teleprocessing equipment, a commercial telephone line was necessary. The monthly charge for the service was $29/month or $348/year. No long distance service was required since the computer vendor has an "800" telephone number.

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* These costs are based on Boeing Computer Service rates - the Corps of Engineers vendor at the time of the PET.

The terminal equipment for the PET was a Teletype 43 terminal with a 30 character per second acoustical modem. This equipment can be purchased for $1,500. Since the terminal supports three systems (two in addition to PAVER), only one-third of the cost was assigned to the PET as an initial cost ($500). Paper needed to support the PAVER system is approximately one box per year at a cost of $21.00. These costs are summarized in Table 7.

(2) Estimated Data Comparison: As for alternative 1, the activities performed during a normal year have been categorized into six groups. The costs for these groups (Table 8) were estimated through discussion with Chief, Building and Grounds and a breakdown of costs and times shown in Table 3. The annual cost has been divided into $8,415 for labor, and $2,948 for computer costs. The computer support cost calculations are shown in Table 9. To reduce overall costs, a tape mount system was assumed to be used in normal annual operation of the PAVER system. A summary of estimated costs for PAVER implementation is presented in Table 10. The initial costs shown are based on the initial cost of the PET (Table 2).

*Benefits - Alternative 2*

(1) Tangible Benefits: Analysis of specific projects indicated that the use of PAVER could reduce cost of maintenance and have an effect on long-term cost avoidance. One specific project was the Branch IWASN Section 04 (Washington Blvd). As obtained from the installation Contracting Office, the bid price for reconstruction of this section was $50,417.25. This section was scheduled for an overlay; however, based on its rate of deterioration (from a second PCI inspection), the overlay was estimated to only last 5 years. The reconstruction, on the other hand, is estimated to have a design life of 25 years. The overlay price would have been approximately $12,173 based on current competitive bid prices. Over the design life of the reconstruction, five overlays would have had to have been placed, resulting in a total cost of $60,865 without inflation. This represents a cost avoidance of $10,448. Other cost avoidances are likely to occur due to timely maintenance through the use of readily available information from PAVER. To quantify this cost avoidance, however, several years of data are needed. Therefore, a conservative cost avoidance of only $10,500 is estimated to occur on an annual basis.

(2) Intangible Benefits: One of the major benefits of using the PAVER system is that the Major Commands will have a uniform method of comparing the pavements at all installations. This will help determine the distribution of maintenance funds and help establish an overall level of service for the installation. This uniform rating will also increase the communication between the Major Commands and the installation engineers. Also, the pavement user will experience greater safety, comfort, and reduced vehicle maintenance because of better overall pavement condition.

At the installation and Major Command level, the PAVER system also adds a great deal of analytical power through programs such as ECON and M&R Guidelines (ref 2). From the PET data, it appears that a time savings of about 2.5 hours can be expected for an economic analysis calculation. This is a benefit to the user, allowing for less computation time. Increased accuracy of the analysis is also expected.

Major benefits experienced at the installation during the PET were that the Work Requirements and M&R guidelines reports were of great use in developing contract documents. These reports provided quantities and cost estimates of the maintenance activities which could take a considerable amount of time to calculate by hand. The quantities were then used in the project preparation phase. The time savings is reflected in the last inputs in Table 3. It was considered to have been impossible to turn out the number of year-end projects (36) without the PAVER system. Having the data stored saved a considerable amount of time in locating documents and reduced the time of field measurements since only spot checking was necessary.

*Other Advantages*

PAVER also offers the user access to factual data about the condition of the pavement system. Under the current system, this data is the subjective opinion of the pavement engineer. Provision of the objective data allows for more accurate calculations and sounder management decisions. Also, the PAVER system will provide a means for a new pavement engineer to become familiar with the overall network condition and inventory in a short time.

## Results of Economic Analyses

The results of the economic analyses are presented in Tables 11 and 12 for the "PET Data Comparison" and "Estimated Data Comparison," respectively. The present worth analysis was performed for an 8-year analysis period assuming a 10 percent interest rate. The analysis was repeated for inflation rates of 0, 5, 10, and 15 percent, respectively. The following is a brief definition of the terminology used in Tables 11 and 12.

(1) Initial Cost: A one-time cost realized at the beginning of the analysis period.

(2) Present Value: The cost in today's dollars of the initial cost plus the discounted amount of future costs.

(3) Equivalent Uniform Annual Cost (EUAC): The present value amortized over the analysis period (present value multiplied by capital recovery factor).

(4) EUAC/Lane Mile: The EUAC divided by the total number of lane miles of pavement inventoried.

(5) Total Benefits: The total amount of tangible benefits (in this case, cost avoidance) realized over the analysis period. The total benefits are not discounted.

## SUMMARY AND CONCLUSIONS

The economic analysis of the PAVER Prototype Evaluation Test (PET) at a military installation has been presented. Two analyses were performed: (1) an analysis based strictly on the data collected during the 4-month PET (PET Data Comparison) and (2) an analysis based on an average annual estimated data (Estimated Data Comparison). The estimated data were based on the PET data and input from the installation Buildings and Grounds Division Chief.

The results of the economic analyses for the "PET Data Comparison" and the "Estimated Data Comparison" are shown in Tables 11 and 12, respectively. The results of the "PET Data Comparison" for 5 percent inflation are plotted in Figure 2. The figure clearly shows that the annual cost of pavement management using PAVER is approximately 50 percent of the cost of the current system.

The results of the "Estimated Data Comparison" for 5 percent inflation are plotted in Figure 3. The figure shows that the annual cost of pavement management using PAVER is approximately 30 percent of the cost of the current system.

## REFERENCES


1. System 2000 is a registered trademark of the INTEL Corporation.

2. Shahin, M. Y., and S. D. Kohn, "Pavement Maintenance Management for Roads and Parking Lots," Technical Report M-294, U.S. Army Construction Engineering Research Laboratory (December 1981).

3. Shahin, M. Y., and S. D. Kohn, "Overview of the PAVER Pavement Management System," a paper submitted for presentation at the 1982 TRB annual meeting.

NAME: _____

ACTIVITY DESCRIPTION: _____

| RESOURCES | PAVER | PREVIOUS METHODS | REMARKS |
|---|---|---|---|
| COMPUTER COST | | | |
| LABOR HOURS & RATE | | | |

Fig 1. Form Used to Record Time and Cost Data During PET

## PET DATA COMPARISON

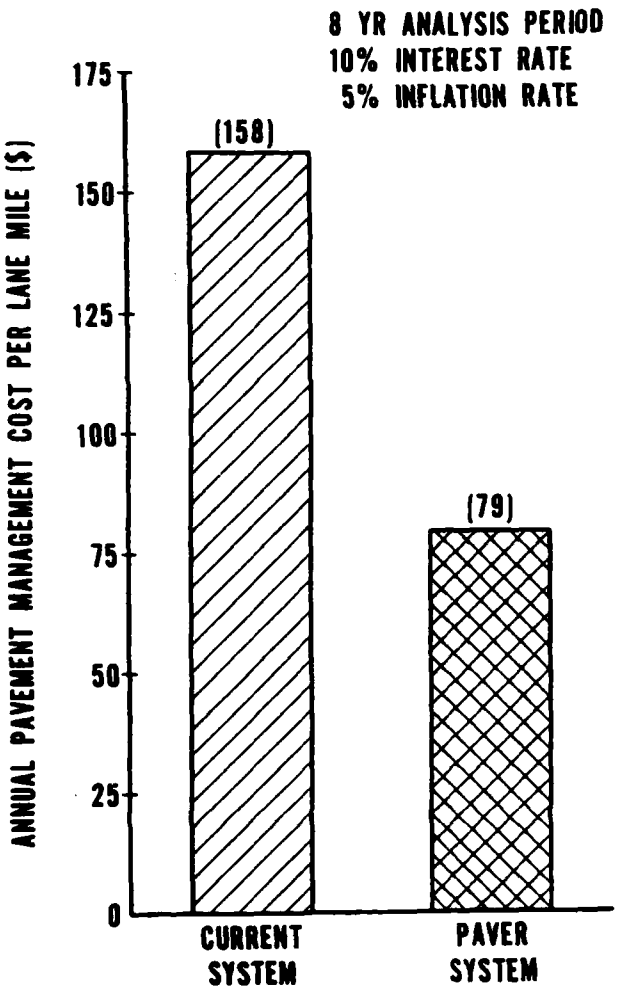


Fig 2. Comparison of Annual Pavement Management Cost Per Lane Mile Based on PET Data.

## ESTIMATED DATA COMPARISON

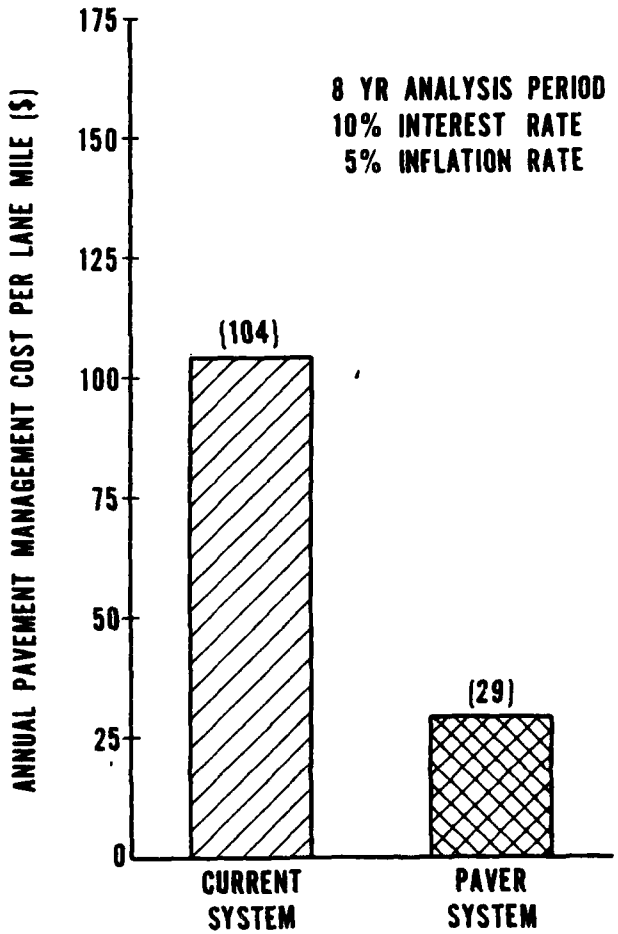


Fig 3. Comparison of Annual Pavement Management Cost Per Lane Mile Based on Estimated Normal Year Data

## TABLE 1A

## ESTIMATED COST BREAKDOWN OF PAVER PET INITIATION

| Item | Cost ($) |
|---|---|
| Inspection | 64,800 |
| Coring | 15,650 |
| Keypunch | 1,650 |
| Data verification | 9.000 |
| Contract overhead | 327 |
| SUBTOTAL | 91,427 |
| Additional computer input cost | 1,000 |
| TOTAL | $92,427 |
| Total Lane Mile Cost | $436/lane mile* |
| Lane Mile Cost of Inspection | $306/lane mile |

*1 lane mile = 12.5' x 5280' = 7330 SY

## TABLE 1B

## AMOUNT OF PAVEMENT SURVEYED

| Branch* Use | No. of Branches | No. of Sections** | Equiv. Lane mi | Total Sec. Area (SY) |
|---|---|---|---|---|
| Roadway | 94 | 188 | 78 | 569,862 |
| Parking | 75 | 224 | 88 | 648,500 |
| MTRPOOL | 2 | 7 | 25 | 181,569 |
| Runway | 1 | 1 | 4 | 26,431 |
| Taxiway | 0 | 0 | 0 | 0 |
| Apron | 4 | 4 | 16 | 121,875 |
| Helipad | 1 | 1 | 1 | 7,147 |
| TOTAL | 177 | 425 | 212 | 1,555,384 |

Total No. of Sample Units***: 5198
Total No. of Samples Inspected: 2637
Sampling Rate: 50.7 percent

*A "Branch" is an easily identifiable entity of the network such as Washington Blvd., etc.

**A "Section" is a portion of a Branch that is uniform in construction history, structure composition traffic, etc.

***A "Sample Unit" is an inspection unit approximately 2500 sf for asphalt sections and 20 slabs for jointed concrete pavements.

TABLE 2

ESTIMATED FULL-SCALE PAVER IMPLEMENTATION COST AT 15 PERCENT SAMPLING RATE

| Activity | Contract Cost ($) |
|---|---|
| Inspection | 19,100 |
| Keypunch (or input) | 500 |
| Data Verification | 2,600 |
| Computer Time | 1,000 |
| Coring | 15,650 |
| Terminal Equipment | 500 |
| Total | $39,350 |

TABLE 3

SUMMARY OF PAVER USAGE AND ESTIMATES OF CURRENT SYSTEM TIME

| Date | Activity | PAVER Time, (Hrs) | PAVER Computer Charge Unit (ccu) | Current Time (Hrs) |
|---|---|---|---|---|
| 6/3/81 | Develop 200K Bids for SAF | 4 | 135.561 | |
| 6/8/81 | List of Work Req. | .25 | 217.222<br>23.110 | |
| 6/13/81 | Edit Cost in Work Req. | 1.5 | 598.786 | |
| | Generate Work Req. Rpts. and Add Sect. to Work Req. | 1 | 258.121 | |
| 6/20/81 | Develop Cont. Projects | .25 | 187.407 | |
| 6/14/81 | Develop BMAR Plan | | | 11 |
| 6/20/81 | Generate Work Req. | .5 | 116.445 | |
| 6/20/81 | Generate Areas | .5 | 29.177 | |
| 6/22/81 | Inspection | | | 2 |
| 6/24/81 | Inspection | | | 2 |
| 7/81 | M&R Proj. Devel. Phase I & II | 120 | | 480 |
| | TOTAL | 175.25 | 5796.393 | 582.5 |

TABLE 4

COMPUTER TIME PRIORITIES, COSTS, AND PERCENTAGES

| Priority | ccu Cost $ | Percent Use |
|---|---|---|
| P01 | .015 | 20 |
| P02 | .025 | |
| P04 | .05 | |
| P06 | .06 | 30 |
| P10 | .075 | 10 |
| P15 | .12 | 40 |
| Weighted Avg. Cost | $.0765 | 100% |

TABLE 5

COST OF CURRENT METHOD FROM PET DATA

"PET Data Comparison"

| Item | Man Hours (4 month) | Avg. Hrly. Rate | 4-Month Cost | Annual Cost |
|---|---|---|---|---|
| Labor | 582.5 | $15.00 | $8,739.5 | 26,200 |
| | | | Total | $26,200 |

TABLE 6

ESTIMATED ANNUAL ACTIVITIES AND COSTS - CURRENT OPERATING METHOD
"Estimated Data Comparison"

| Activity | Hrs. | Avg. Hrly. Rate ($/hr) | Cost $ |
|---|---|---|---|
| Periodic Pavement Inspection | 160 | 13.44 | 2,150 |
| Determine M&R Requirements and Set M&R Priorities | 240 | 15.74 | 3,778 |
| Validation of M&R Projects | 80 | 15.00 | 1,200 |
| Annual Work Plan | 80 | 14.26 | 1,141 |
| Long Range Planning | 160 | 15.74 | 2,518 |
| M&R Cost Estimating | 480 | 13.44 | 6,451 |
| TOTALS | 1200 Hrs. | | $17,238 |

TABLE 7

COSTS OF PAVER FROM PET DATA
**"PET Data Comparison"**

| Item | Man Hours (4 month) | Avg. Hrly. Rate | 4-Month Cost | Annual Cost | Initial Cost |
|---|---|---|---|---|---|
| Labor | 175.25 | $15.00 | $2629 | $7886 | |
| Computer ccu's ($.0765/ccu) | | | $443 | $1330 | |
| Computer Connect | 15.13 | $8.50 | $129 | $386 | |
| Disc storage | | | | $1848 | |
| Communication Line (telephone) | | | | $348 | |
| Paper | | | | $21 | |
| Terminal Equipment | | | | | $500 |
| Initiation cost | | | | | $92,437 |
| | | | Total | $11,819 | $92,927 |

## TABLE 8

## ESTIMATED ANNUAL ACTIVITIES AND COSTS - PAVER SYSTEM
"Estimated Data Comparison"

| Activity | Time Hrs. | Avg. Hrly. Rate ($) | Cost ($) |
|---|---|---|---|
| Periodic Pavement Inspection | 160 | 13.44 | 2150 |
| Determine M&R Requirements and Set Priorities | 96 | 15.67 | 1504 |
| Validation of M&R Projects | 40 | 15.00 | 600 |
| Annual Work Plan | 40 | 14.26 | 570 |
| Long-Range Planning | 24 | 15.74 | 378 |
| M&R Cost Estimating | 120 | 13.44 | 1613 |
| FESA Support 12 mm/all bases | | | 1600* |
| Labor Subtotal | | | 8415 |
| Computer support | | | 2948 |
| TOTAL | 480 Hrs. | | $11,363 |

*25 Installations requiring one man year GS 12 - $26,951 x 1.5 (overhead) = $40,000
per base = $40,000/25 base installations
= $1600/installation

## TABLE 9

## ESTIMATED ANNUAL COMPUTER SUPPORT COSTS
"Estimated Data Comparison"

| | | |
|---|---|---|
| 1. Tape Loading - 2 times per week | | |
| | (2 time/week)(52 wk/yr)($6/mount) | = $624 |
| 2. Update Tape | | |
| | (2 tapes)(35 times/yr)($6/mount) | = $420 |
| | | Subtotal $1,044 |
| 3. Tape Storage | | |
| | (2 tapes)($.25/day)(365 day/yr) | = $183 |
| 4. On-Line Storage (disc space) | | |
| $22/1000 sectors/month | | |
| Avg. data base size 8000 sectors | | |
| Assume tape loaded to disc 2 month/yr | | |
| Annual cost ($22)(8)(2) | | = $352 |
| | | Subtotal $1,579 |
| 5. Phone Line | | $348 |
| 6. Paper | | $ 21 |
| 7. Computer time cost | | $1000 |
| | | TOTAL $2,948 |

TABLE 10

SUMMARY OF ESTIMATED COSTS FOR PAVER IMPLEMENTATION
"Estimated Data Comparison"

| Initial Cost ($) (see tables 1, 2) | Annual Labor Cost ($) (see table 8) | Annual Computer Support Cost ($) (see table 9) |
|---|---|---|
| 39,350 | 8415 | 2948 |

TABLE 11

SUMMARY OF ECONOMIC ANALYSIS FROM PET DATA
"PET Data Comparison"

A. Current Method
Interest Rate: 10% Analysis Period: 8 yr.

| Inflation Rate (%) | Present Value ($) | EUAC* ($) | EUAC Lane Mile ($) | Total Benefits ($) |
|---|---|---|---|---|
| 0 | 153,752 | 28,820 | 136 | 0 |
| 5 | 179,120 | 33,575 | 158 | 0 |
| 10 | 209,600 | 39,288 | 185 | 0 |
| 15 | 246,156 | 46,140 | 218 | 0 |

B. PAVER System
Interest Rate: 10% Analysis Period: 8 yrs

| Inflation Rate (%) | Present Value ($) | EUAC ($) | EUAC Lane Mile ($) | Total Benefits ($) | Present Value - Total Benefits ($) | EUAC Lane Mile (Including Benefits) ($) |
|---|---|---|---|---|---|---|
| 0 | 162,286 | 30,420 | 143 | 84,000 | 78,286 | 69 |
| 5 | 173,729 | 32,565 | 154 | 84,000 | 89,729 | 79 |
| 10 | 187,479 | 33,142 | 166 | 84,000 | 103,479 | 92 |
| 15 | 203,969 | 38,233 | 180 | 84,000 | 119,969 | 106 |

*Equivalent Uniform Annual Cost.

TABLE 12

SUMMARY OF ECONOMIC ANALYSIS ESTIMATED ANNUAL COST DATA
"Estimated Data Comparison"

A. Current Method - Estimated Costs
Interest Rate: 10% Analysis Period: 8 yr.

| Inflation Rate (%) | Present Value ($) | EUAC ($) | EUAC Lane Mile ($) | Total Benefits ($) |
|---|---|---|---|---|
| 0 | 101,160 | 18,962 | 89 | 0 |
| 5 | 117,850 | 22,090 | 104 | 0 |
| 10 | 137,904 | 25,849 | 122 | 0 |
| 15 | 161,955 | 30,358 | 143 | 0 |

B. PAVER System -
Interest Rate: 10% Analysis Period: 8 yrs

| Inflation Rate (%) | Present Value ($) | EUAC ($) | EUAC Lane Mile ($) | Total Benefits ($) | Present Value - Total Benefits ($) | EUAC Lane Mile (Including Benefits) ($) |
|---|---|---|---|---|---|---|
| 0 | 106,027 | 19,874 | 93 | 84.000 | 22,027 | 20 |
| 5 | 117,027 | 21,936 | 115 | 84,000 | 33,027 | 29 |
| 10 | 130,246 | 24,414 | 115 | 84,000 | 46,246 | 41 |
| 15 | 146,099 | 27,385 | 129 | 84,000 | 62,099 | 55 |

CERL DISTRIBUTION

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ATTN: DAEN-CWE
ATTN: DAEN-CWM-R
ATTN: DAEN-CWO
ATTN: DAEN-CWP
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ATTN: DAEN-MPC
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ATTN: DAEN-MPR-A
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Japan 96343
Kansas City 64106
Little Rock 72203
Los Angeles 90053
Louisville 40201
Memphis 38103
Mobile 36628
Nashville 37202
New Orleans 70160
New York 10007
Norfolk 23510
Omaha 68102
Philadelphia 19106
Pittsburgh 15222
Portland 97208
Riyadh 09038
Rock Island 61201
Sacramento 95814
San Francisco 94105
Savannah 31402
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Middle East (Rear) 22601
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New England 02154
North Atlantic 10007
North Central 60605
North Pacific 97208
Ohio River 45201
Pacific Ocean 96858
South Atlantic 30303
South Pacific 94111
Southwestern 75202

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HQ, 7th Army ODCS/Engr. 09403
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V. Corps 09079
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21st Support Command 09325
ATTN: AEREH (5)
Berlin 09742
ATTN: AEBA-EN (2)
Southern European Task Force 09168
ATTN: AESE-ENG (3)
Installation Support Activity 09403
ATTN: AEUES-RP

8th USA, Korea
ATTN: EAFE (8) 96301
ATTN: EAFE-Y 96358
ATTN: EAFE-ID 96224
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Papers presented at the 61st annual meeting of the Transportation Research Board, January 1982.

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